PETITIONED PUBLIC HEALTH ASSESSMENT

AMOCO OIL COMPANY
(a/k/a AMOCO OIL COMPANY - SUGAR CREEK (FINDS) SS#0716)
SUGAR CREEK, JACKSON COUNTY, MISSOURI
EPA FACILITY ID: MOD007161425

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Prepared by:

Petition Response Section
Exposure Investigations and Consultation Branch
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry

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LIST OF ACRONYMS AND ABBREVIATIONS

AML	Acute myelogenous leukemia

Amoco	Amoco Oil Company
ATSDR	Agency for Toxic Substances and Disease Registry
BTEX	Benzene, toluene, ethyl benzene, and xylene
CREG	Cancer risk evaluation guide
Conc.	Concentration
DRO	Diesel range organics
EMEG	Environmental media evaluation guide
EPA	Environmental Protection Agency
ft	Foot
GRO	Gasoline range organics
IEMEG	Intermediate environmental media evaluation guide
J	Estimated concentration
kg	Kilogram
L	Liter
LPG	Liquified petroleum gases
m^3	Cubic meter
Max.	Maximum
MCL	Maximum contaminant level
mg	Milligrams
MS	Multiple sclerosis
ND	Not detected
NOAEL	No-observed-adverse-effect level
PAHs	Polynuclear aromatic hydrocarbons
PCE	Tetrachloroethene
ppb	Parts per billion
ppbv	Parts per billion volume
ppm	Parts per million
RBC(n)	Risk-based concentration - noncancer
RCRA	Resource Conservation and Recovery Act
RfC	Reference concentration
RFI	RCRA Facility Investigation
RMEG	Reference dose media evaluation guide
SVOCs	Semi-volatile organic compounds
TCE	Trichloroethene
TLV	Threshold limit value
TPH	Total petroleum hydrocarbons
µg	Microgram

VOCs Volatile organic compounds

Next Section

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1. SUMMARY

In June 1998, the Agency for Toxic Substances and Disease Registry (ATSDR) received a petition to conduct a public health assessment of a former petroleum refinery, the Amoco Oil Company site, in Sugar Creek, Missouri. The petitioner believes the incidences of various types of cancers, Alzheimer's, multiple sclerosis, and nervous disorders are directly related to contaminants migrating from the site. The Norledge area, adjacent to the southern boundary of the site, was described as an area at particular risk for off-site migration of contaminants. The Norledge area of Sugar Creek encompasses approximately 100 residences.

ATSDR reviewed off-site groundwater, soil, soil gas, and air data from the Norledge area. ATSDR evaluated pathways of human exposure to determine whether nearby residents are exposed to contamination. From this evaluation, ATSDR determined that past, current, and future completed exposure pathways to indoor air exist for residents who live in the Norledge area. A potential exposure pathway was identified for subsurface soil in the Norledge area. No direct exposures to groundwater or soil gas were identified in the Norledge area.

On the basis of available environmental and toxicologic information, ATSDR concluded that the Norledge area, adjacent to the Amoco Oil Company site in Sugar Creek, Missouri, poses *no apparent public health hazard*. Short-term exposures to the contaminant levels detected during indoor air sampling events are not likely to be associated with adverse health effects. Potential intermittent exposures to subsurface soils in the Norledge area during drilling, building, and excavating would be unlikely to result in adverse health effects, although workers should avoid contact with free product (crude oil) that may be encountered during these types of activities.

The maximum (highest) concentrations of contaminants detected in groundwater and soil gas exceeded health-based comparison values. However, as far as ATSDR has been able to determine, no residents are using this contaminated groundwater as a drinking water source. Furthermore, no residents are experiencing direct exposures to soil gas.

Based on the information reviewed for this public health assessment, ATSDR recommends the following:

- prevent potential future exposures to contaminated groundwater, including the placement of institutional controls on the installation of wells in areas of known groundwater contamination;
- continue to remediate contaminated groundwater in the Norledge area; and
- take precautionary measures to prevent worker and resident exposures to free product that may be encountered during drilling, building, and excavating subsurface soil in the Norledge area.

Summary update:

ATSDR previously concluded in a May 1999 public comment version of this public health assessment that the Amoco Oil Company site in Sugar Creek, Missouri, posed an *Indeterminate public health hazard* [1]. This determination was made, at that time, because insufficient air data were available to evaluate chronic (long-term) indoor air exposures and because no surface soil data (top 0-3 inches) were available to evaluate off-site conditions for public health significance. ATSDR recommended sampling indoor air and surface soil in the Norledge area. The Environmental Protection Agency (EPA) immediately collected the requested data

and ATSDR evaluated the data in two subsequent ATSDR documents. Because the agency's evaluations of the additional data concluded that no adverse health effects would be likely to result from chronic exposure to indoor air or surface soil, ATSDR removed the recommendations to sample indoor air and surface soil from this public health assessment (see Section 5.1 and 5.3).

2. PURPOSE AND HEALTH ISSUES

The Agency for Toxic Substances and Disease Registry (ATSDR) was petitioned on June 13, 1998, to produce a public health assessment of the Amoco Oil Company (Amoco) site in Sugar Creek, Missouri. The petitioner believes the incidences of various types of cancers, Alzheimer's, multiple sclerosis, and nervous disorders are directly related to contaminants migrating from the site.

As an initial step in the public health assessment process, ATSDR typically visits a site to gather information from area residents about their health concerns. For the Amoco site, ATSDR collected this information from about 12 residents during a meeting held in Sugar Creek in July 1998. Additionally, ATSDR received numerous telephone calls from residents reporting health concerns. Residents reported having high stress levels in their community from worrying about environmental contamination. The Norledge area, adjacent to the southern boundary of the site, was described as an area at particular risk for off-site migration of contaminants.

Residents are also concerned about past air exposures from when the facility was operating. No air data exist from this time frame; however, ATSDR was informed in October 2000 that there may be some limited groundwater data from the 1960s and 1970s that could be used to model past indoor air concentrations. If modeling is feasible, the information it provides may assist in addressing community concern about past indoor air exposures.

Based on the information currently available to the agency, this public health assessment focuses on the following:

- a review of off-site groundwater, soil, soil gas, and air data from the Norledge area to determine if current exposures are of potential health concern for local residents;
- a review of information on chemicals associated with this site to determine whether there is any known association between these contaminants and risk to human health; and,
- a plan identifying future ATSDR activities and any need for additional information.

3. BACKGROUND

3.1 Site Description and History

The Amoco Oil Company (Amoco) began petroleum refinery operations in Sugar Creek, Missouri, in 1904. Crude oil was brought in by pipeline from several states to produce gasoline, distillate fuels, jet fuels, residual fuels, asphalt, petroleum coke, liquified petroleum gases (LPG), sulfur, and polymers (TriTechnics Corporation, 1995b). Although petroleum refinery operations ceased in 1982, Amoco has continued to use portions of the site as a light oil petroleum product marketing terminal, a pipeline facility, and an asphalt receiving and processing center (TriTechnics Corporation, 1995b).

While the refinery was operational, the site consisted of numerous process units. In addition to these process units, several storage tank areas existed. Active and inactive underground pipelines currently run throughout many portions of the site. Starting in the 1970s, Amoco began to replace underground pipelines with above-ground pipelines to reduce the potential for undetected releases (TriTechnics Corporation, 1995b).

Landfarming occurred and there were sludge EXIT pits, sludge lagoons EXIT, and sludge ponds. Numerous spills and leaks of crude oil occurred throughout the site.

Refinery operations were regulated under the Resource Conservation and Recovery Act (RCRA). When refinery operations ceased, a RCRA Facility Investigation (RFI) identified potential sources, areas, and characteristics of contamination to be investigated (TriTechnics Corporation, 1995b). Remedial activities occurred and are still occurring on-site.

3.2 Land and Natural Resource Use

The Amoco site occupies approximately 500 acres on both sides of Sugar Creek (see Figure 1, Appendix A). The Missouri River bounds the site to the north, wooded areas are on the East Bluff and West Bluff, and residential areas are to the south (TriTechnics Corporation, 1995b). The Norledge area is located adjacent to the south side of the site. The Atchison Topeka & Santa Fe and Missouri Pacific railroad lines run through the northern portion of the site.

Most of the former refinery is situated on the bluffs of the Missouri River approximately 100 to 200 feet higher in elevation than the river basin (TriTechnics Corporation, 1995b). Much of the site has become overgrown with vegetation and many areas are covered with dense trees, shrubs, and grasses; however, a few sparsely vegetated areas exist.

Sugar Creek was incorporated in the 1920s. Initially, residents were provided with municipal water through the Kansas City water system (ATSDR, 1999a). In 1956, the city of Independence built a water treatment plant and assumed the responsibility of supplying Sugar Creek with municipal water. A groundwater well survey was conducted in the Norledge area to determine the potential for possible residential ingestion of groundwater by residents (TriTechnics Corporation, 1995b). Results indicated that residents in the Norledge area were not using groundwater as a source of drinking water (TriTechnics Corporation, 1995b).

3.3 Physical Hazards

Access restrictions to the site include a fence and natural barriers (like water and steep cliffs). ATSDR identified numerous physical hazards on the site including rusty pipes sticking out of the ground, rusty barrel fragments, old manholes, drainage lines, drains, old construction debris, steep inclines, small springs, and heavy vegetation. Amoco recently reviewed the issue of site access, with specific focus on the risk of unlawful entry, and is currently making further improvements to site access control.

3.4 Demographics

According to the 1990 U.S. Census of Population and Housing (U.S. Bureau of the Census, 1991), the demographic statistics for locations within 1 mile of the Amoco site indicated there were 10,148 persons residing in 4,468 households. Of these, 97% were white; 0.4% were black; 0.7% were American Indian, Eskimo, Aleut; 0.9% were Asian or Pacific Islander; and 1% were members of other races. There were 1,119 children 6 years of age or younger, and 1,338 adults 65 years of age and older. Please refer to Figure 2, Appendix A, for additional demographic statistics.

4. DISCUSSION

ATSDR evaluates contaminants detected in environmental media at hazardous waste sites and determines whether an exposure to the contamination has public health significance. ATSDR begins this evaluation process by gathering reports that contain relevant environmental data for the site. These data are reviewed to determine if the levels of contaminants are above health-based comparison values. Health-based comparison values are media-specific concentrations of chemicals that are not likely to result in adverse health effects

under default conditions of exposure. Please refer to Appendix C for further information on health-based comparison values.

Once the environmental data have been obtained and evaluated, ATSDR staff determine whether people were, or continue to be, exposed to the contaminants. ATSDR evaluates the factors that lead to human exposure. These factors, called elements, include (1) a source of contamination, (2) a transport through an environmental medium, (3) a point of exposure, (4) a route of human exposure, and (5) an exposed population. Exposure pathways fall into one of three categories:

- *Completed Exposure Pathway*. ATSDR calls an exposure pathway "complete" if it is certain that people are exposed to contaminated media. Completed exposure pathways must include all five elements and indicate that human exposure to the contaminant has occurred, is occurring, or will occur.

- *Potential Exposure Pathway.* Potential exposure pathways are those in which at least one of the five elements is missing but could exist. Potential exposure pathways indicate that exposure to a contaminant could have occurred, could be occurring, or could occur in the future. Potential exposure pathways are those that have (1) documented exposure, but there is insufficient information available to determine whether the environmental medium is contaminated, or (2) a documented environmental medium that is contaminated, but it is unknown whether people have been, or may be, exposed to the medium.

- *Eliminated Exposure Pathway*. An eliminated exposure pathway is one in which at least one of the five elements is missing and will never be present. From a human health perspective, pathways can be eliminated from further consideration if ATSDR is able to show that (1) an environmental medium is not contaminated, or (2) no one is exposed to contaminated media.

Numerous environmental investigations have occurred both on and off the Amoco site. For the purpose of this public health assessment, ATSDR's evaluation focused on off-site air, the environmental pathway most likely to lead to human exposure. Off-site soil gas also was evaluated to determine the extent to which contaminated groundwater may affect the air pathway. ATSDR reviewed recently collected environmental data on groundwater and soil from the Norledge area to address community concern about environmental contamination of this area. An evaluation of on-site data is not included in this public health assessment. Table 1, Appendix B, contains a description of the off-site exposure pathways for this site. The following text provides ATSDR's evaluation of off-site groundwater, soil, soil gas, and air data.

4.1 Groundwater

Area groundwater investigations at the site have identified 11 on-site areas of benzene contamination encompassing 68 acres. Additionally, 13 on-site, free product plumes are estimated to encompass 73 acres of the former refinery (TriTechnics Corporation, 1995b). One off-site area of benzene contamination and two off-site areas of free product contamination were identified in the Norledge area. The RCRA Facility Investigation Report (RFI) concluded that it appears the plume migration in the Norledge area is the result of transport, at least in part, via a migration pathway other than groundwater (i.e., underground utility corridors) (TriTechnics Corporation, 1995b). Amoco began efforts to recover free product in the late 1950s and to control the migration of hydrocarbons dissolved in groundwater in the 1960s through construction of interceptor drain systems and trenches (TriTechnics Corporation, 1995b). This program was expanded in the 1970s and 1980s with the construction and expansion of the Norledge Interceptor Trench Recovery Network.

In March and April 1996, groundwater samples were collected primarily in the Norledge area to determine the presence of contaminants in the subsurface and to conceptualize the extent and magnitude of hydrocarbon contamination in the area (EnviroRemedy International, Inc., 1996). Split groundwater samples were also obtained during this sampling event (TriTechnics Corporation, 1996). The groundwater samples were

analyzed by separate laboratories for volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs). Please refer to Table 2, Appendix B, for the groundwater sampling results.

From May 5 to May 27, 1997, groundwater data were collected in the Norledge area to support the evaluation of potential corrective measures (Amoco Oil Company, 1997). Samples were collected from 15 newly installed wells and from 17 previously existing wells throughout the Norledge area (both on-site and off-site), the Norledge Interceptor Trench (near the sump), and the fire station (see Figure 3, Appendix A). These groundwater samples were analyzed for benzene, toluene, ethyl benzene, xylene (BTEX); diesel range organics (DRO); and gasoline range organics (GRO). Benzene levels ranged from non-detect to a high of 931 micrograms per liter (µg/L) in monitoring well MW-106 in the off-site Norledge area. Of note, the maximum level detected at the Norledge Interceptor Trench was 18,800 µg/L and at the fire station was 308 µg/L. Please refer to Table 2, Appendix B, for the results of the off-site Norledge area groundwater data.

A Limited Subsurface Investigation was performed in July 1998 at selected properties (primarily in the Norledge area) to determine whether petroleum hydrocarbons had impacted the area. During the July 1998 Limited Subsurface Investigation, groundwater samples were collected from test holes P-1 and P-2 (see Figure 4, Appendix A) and analyzed for BTEX; total petroleum hydrocarbons (TPH) for both gasoline and diesel range organics; and chlorinated hydrocarbons (Hydro-LOGIC, Inc., 1998a). Benzene was detected at a maximum concentration of 2,560 µg/L (sample location P-2). Please refer to Table 2, Appendix B, for the results of this sampling event.

During the July 1998 Limited Subsurface Investigation, groundwater samples were collected from two private wells and analyzed for BTEX and TPH (for both gasoline and diesel range organics). No residents currently use private groundwater wells for household purposes. Please refer to Table 3, Appendix B, for the results of this sampling event.

On December 15 and 16, 1998, groundwater samples were collected from test holes P-8A, P-11 and P-13 and analyzed for BTEX and TPH (for both gasoline and diesel range organics) (Hydro-LOGIC, Inc., 1998b). Split groundwater samples collected from locations P-8A and P-13 were sent to a different laboratory and analyzed for BTEX , TPH (for both gasoline and diesel range organics), methyl-tert-butyl-ether (MTBE), and naphthalene (Pace Analytical, 1998c). Amoco contractors also collected groundwater samples from locations P-8A, P-11, and P-13 at this time and analyzed them for BTEX, TPH, and MTBE (Southwest Laboratory of Oklahoma, Inc., 1999). Please refer to Table 2, Appendix B, for the results of the December 1998 sampling events.

In March 1999, groundwater samples were collected from locations designated as "Trench" and "LB". These locations were analyzed for BTEX and TPH (Pace Analytical, 1999a). On April 15, 1999, groundwater samples were collected from three test holes and analyzed for BTEX, TPH (for both gasoline and diesel range organics), and MTBE (Hydro-LOGIC, Inc., 1999). Amoco contractors also collected groundwater samples on April 15, 1999, and analyzed them for BTEX and TPH (ThermoRetec, 1999). One additional groundwater split sample was collected on April 15, 1999, and analyzed for BTEX , TPH (for both gasoline and diesel range organics), MTBE, and naphthalene (Pace Analytical, 1999b). Please refer to Table 2, Appendix B, for the results of these sampling events.

The site and surrounding area have been provided with municipal drinking water since the 1920s; therefore, past and current exposures to Norledge area groundwater constitute an eliminated exposure pathway. ATSDR is not aware of any restrictions on the installation of private wells in the Norledge area. ATSDR defines future exposure to off-site groundwater in the Norledge area as a potential exposure pathway. Potential routes of exposure include dermal contact, inhalation, and ingestion.

4.2 Soil

Soil investigations have occurred on-site from randomly selected locations in process and storage tank areas, and specific locations in focused investigation areas at the former refinery (TriTechnics Corporation, 1995b).

The RFI identified lead and benzo(a)pyrene as primary contaminants of concern in surface soil and lead, benzene, and benzo(a)pyrene as primary contaminants of concern in subsurface soil. Off-site subsurface soil samples collected and analyzed for these contaminants of concern in the Norledge area are described in the following paragraphs.

In March and April 1996, subsurface soil samples were collected primarily in the Norledge area to determine the presence of contaminants in the subsurface and to conceptualize the extent and magnitude of hydrocarbon contamination in the area (EnviroRemedy International, Inc., 1996). The subsurface soil samples were analyzed by separate laboratories for VOCs and SVOCs. Please refer to Table 4, Appendix B, for the soil sampling results.

During a July 1998 Limited Subsurface Investigation, subsurface soil samples were collected from ten test holes labeled P-1 through P-10 (see Figure 4, Appendix A) and analyzed for BTEX and TPH (for both gasoline and diesel range organics). Three of the soil samples were also analyzed for chlorinated hydrocarbons and four of the soil samples were analyzed for polynuclear aromatic hydrocarbons (PAHs). No compounds were detected above ATSDR comparison values. Please refer to Table 4, Appendix B, for the results of this sampling event.

During a December 1998 Limited Subsurface Investigation, subsurface soil samples were collected from four test holes and analyzed for BTEX and TPH (Hydro-LOGIC, Inc., 1998b). Amoco contractors also collected subsurface samples from several locations at this time and analyzed them for BTEX, TPH, and MTBE (Southwest Laboratory of Oklahoma, Inc., 1999). BTEX and MTBE were not detected above ATSDR's comparison values in these sampling events. Please refer to Table 4, Appendix B, for the results of these sampling events.

Also in December 1998, three test pits were excavated to assess subsurface conditions in the vicinity of a proposed sanitary sewer excavation planned along Willow Street and Burton Street (Amoco, 1998). Two soil samples were collected and analyzed for TPH and benzene. One of the samples indicated TPH at 127 milligrams per kilogram (mg/kg) which was above the State of Missouri Cleanup Standards for Hydrocarbon Contaminated Soil. Soil that exceeds this standard (50 mg/kg) will be managed by Amoco as a special waste and taken to a licensed landfill (Amoco, 1998). Table 4, Appendix B, contains the results of this sampling event.

In January 1999, a subsurface soil sample was collected from location P-13A and analyzed for BTEX, TPH, and MTBE (Analytical Report, 1999). BTEX and MTBE were not detected above ATSDR's comparison values. Table 4, Appendix B, contains the results of this soil sample.

During an April 1999 Limited Subsurface Investigation, subsurface soil samples were collected from test holes in the Norledge area and analyzed for BTEX and TPH (Hydro-LOGIC, Inc., 1999). Benzene was detected above ATSDR's CREG comparison value. Amoco contractors also collected subsurface samples at this time and analyzed them for BTEX and TPH (ThermoRetec, 1999). Toluene, ethyl benzene, and xylenes were not detected above ATSDR's comparison values during these sampling events. Please refer to Table 4, Appendix B, for the results of these sampling events.

Present and future potential exposures to subsurface soil by residents and workers could exist because of soil-disturbing activities (e.g., drilling, building, or excavation). These potential exposures to subsurface soil in the Norledge area are likely to be infrequent and primarily limited to dermal contact.

4.3 Soil Gas

As part of the RFI, a subsurface gas sampling program was implemented. Off-site samples were collected from 35 locations primarily in the Norledge area (see Figure 5, Appendix A). The locations were aligned in a grid corresponding to the area of groundwater contamination (TriTechnics Corporation, 1995b). Samples were analyzed for BTEX. Please refer to Table 5, Appendix B, for the results of this sampling event.

Soil gas concentrations do not generally reflect concentrations in the breathing zone because soil gas measurements are obtained by mechanically evacuating volatiles from the soil in order to generate a concentrated sample. During the RFI, soil gas samples were collected from five feet below ground surface; therefore, residents living near the Amoco site are not directly exposed to soil gas. ATSDR defines exposure to soil gas as an eliminated exposure pathway. However, soil gas data does help identify the contaminants that would be important to evaluate in air.

4.4 Air

Sampling of indoor air in the Norledge area was conducted in June 1998 for BTEX and VOCs. Seven residential houses were chosen for sampling on the basis of their location relative to the area where the groundwater and soil gas plumes overlapped (ThermoRetec, 1998). Samples were collected from basements and from ground floor rooms (that were not located above a basement). Indoor (basement) air sampling was also conducted in two control houses located outside the groundwater and soil gas plume area (see Figure 6, Appendix A). Please refer to Table 6, Appendix B, for the results of this sampling event.

In November 1998, sampling of indoor and outdoor air was conducted at two residences in the Norledge area (Pace Analytical, 1998a). The samples were analyzed for BTEX. Split samples were also obtained during this sampling event and analyzed for BTEX as well as other VOCs (Pace Analytical, 1998b). Results of this sampling event are in Table 7, Appendix B.

Sampling of indoor air was conducted on October 21 and 22, 1999, in the basements of eight Amoco-owned homes. The samples were analyzed for benzene, VOCs, total volatile petroleum hydrocarbons, methane, hexane, and ethane (ThermoRetec, 2000). Results of this sampling event are in Table 7, Appendix B.

A past, current, and future completed exposure pathway to indoor air was identified for residential homes in the Norledge area. Benzene, chloroform, 1,4-dichlorobenzene, methylene chloride, tetrachloroethene, and trichloroethene were detected in residential homes at levels above comparison values. People who reside or work in these homes are exposed to these contaminants through inhalation.

5.0 TOXICOLOGIC EVALUATION

In public health assessments, ATSDR addresses the likelihood that exposure to contaminants at the maximum concentrations detected would result in adverse health effects. Although the relative toxicity of a chemical is important, the response of the human body to chemical exposure is determined by several additional factors, including the concentration (how much); the duration of exposure (how long); and the route of exposure (breathing, eating, drinking, or skin contact). Lifestyle factors (e.g., occupation and personal habits) have a major impact on the likelihood, magnitude, and duration of exposure. Individual characteristics (e.g., age, sex, nutritional status, overall health, and genetic constitution) affect how a human body absorbs, distributes, metabolizes, and eliminates a contaminant. A unique combination of all these factors will determine the individual's physiological response to a chemical contaminant and any adverse health effects the individual may suffer as a result of the chemical exposure.

In this section, ATSDR provides a review of information on the chemicals associated with this site to determine whether there is any known association between these contaminants and risk to human health. Because a contaminant generally must first enter the body before it can produce an effect, this evaluation will focus on chemicals of concern in completed pathways of exposure. Please refer to Appendix D for information on ATSDR methodology.

5.1 Air

A past, current, and future completed exposure pathway to indoor air was identified for residential homes in the Norledge area. In the following text, an evaluation of the chemicals benzene; 1,4-dichlorobenzene; chloroform; methylene chloride; tetrachloroethene; and trichloroethene is provided.

5.1.1 Benzene

Benzene was detected in indoor air at several residences above ATSDR's comparison values (see Tables 6 and 7, Appendix B). The highest levels (62 micrograms per cubic meter ($\mu g/m^3$) and 120 $\mu g/m^3$), were detected in basements. The highest concentration of 120 $\mu g/m^3$ was detected in a control home outside the area of groundwater and soil gas contamination (see Figure 6, Appendix A). Endogenous sources (e.g., second-hand tobacco smoke, auto exhaust from attached garages, glues, paints, and other domestic materials containing benzene) may have contributed to the benzene levels detected in these homes.

The highest concentrations of benzene detected in the Norledge area (62 $\mu g/m^3$) and in a control home (120 $\mu g/m^3$) exceeded ATSDR's intermediate environmental media evaluation guide (EMEG) of 4 parts per billion (ppb) or 13 $\mu g/m^3$. This health-based comparison value represents the concentration of benzene in air that is not likely to result in adverse health effects for short-term exposures. However, exceeding a comparison value does not necessarily mean that the contaminant represents a public health threat. This particular intermediate EMEG is based on a behavioral effect (i.e., a facilitated aversion response) observed in male Kunming mice exposed to 780 ppb (2,496 ug/m^3) benzene for 2 hours a day, 6 days a week, for 30 days (Li et al., 1992). To avoid an electrical shock, mice exposed to 780 ppb benzene found their way to a safe area at the end of a "Y" maze more quickly, on average, than did untreated control mice. The intermediate EMEG based on this observed effect includes a safety factor (also known as an uncertainty factor) of 90, an adjustment for intermittent exposure, and a human equivalent concentration adjustment. The maximum concentration of benzene detected in indoor air of residents' homes (120 $\mu g/m^3$ or 37.5 ppb) was significantly below this 780 ppb level and was well below levels that have been associated with central nervous system effects in humans (ATSDR, 1997a). The air data indicate that the residents are not constantly exposed to the highest levels of benzene that were found in their homes, but to benzene levels that fluctuate within their homes. Therefore, none of the benzene exposures in the Norledge area would be expected to produce adverse health effects.

The highest concentrations of benzene detected in the Norledge area exceeded ATSDR's cancer risk evaluation guide (CREG) which is based on long-term (i.e., chronic) exposures. At the time this public health assessment was released for public comment in May 1999, ATSDR was only able to provide some perspective concerning benzene exposures because the air sampling data were insufficient to make a public health determination for chronic exposure. Additional indoor air data have since been collected and evaluated in a March 2000 public health assessment. The median of the indoor air values for samples collected in June and July 1999, was 2.45 $\mu g/m^3$ (or 0.77 ppb) benzene. This median indoor air value is consistent with typical indoor background air levels of 10 $\mu g/m^3$ (or 3.1 ppb). Based on a review of the literature, there are no known adverse health effects in humans associated with benzene exposures in the low parts per billion range (see Appendix E). Considering the levels of chemicals found in indoor air to date and a review of available toxicologic and epidemiologic data, chronic (long-term) exposures to indoor air would not be expected to produce any adverse health effects in Sugar Creek residents. Groundwater and subsurface soil remedial activities in the Norledge area should result in decreasing contaminant concentrations in the future. Therefore, any potential contribution from these media to indoor air levels should decrease as well.

5.1.2 1,4-dichlorobenzene

No adverse health effects would be expected at the maximum level of 1,4-dichlorobenzene detected indoors (3,400 µg/m3). The latter concentration exceeds ATSDR's intermediate EMEG (200 ppb or 1,200 $\mu g/m^3$) by less than 3% of the incorporated safety factor and it exceeds ATSDR's chronic EMEG (100 ppb or 600

$\mu g/m^3$) by less than 6% of the incorporated safety factor. The safety factor for both the intermediate and chronic EMEG is 100 which means the EMEG is 100 times lower than the corresponding no effect level in exposed rats. All known effect levels (including those for "less serious effects") exceeded 50,000 ppb or 300,000 $\mu g/m^3$ of 1,4-dichlorobenzene. Humans may experience nose and eye irritation at 80,000 ppb. The current OSHA permissible exposure limit is 75,000 ppb. Space deodorants for toilets and fumigants for moths, molds and mildews are common sources of 1,4-dichlorobenzene in the home (ATSDR, 1998b).

5.1.3 Other Chemicals

The highest levels of chloroform, methylene chloride, tetrachloroethene (PCE), and trichloroethene (TCE) detected in indoor air were below all comparison values for non-cancer effects, but they did exceed ATSDR's CREGs. ATSDR provides cancer classifications in Appendix I. However, the CREGs for these compounds have limited relevance to humans because all are based primarily on rodent liver tumors produced by species-specific mechanisms that are dependent on unusually high doses. The induction of cancers in mice and rats by these compounds required doses in excess of anything humans might reasonably be expected to encounter, and involved certain elements of rodent biology that are not likely to be shared by humans. The Environmental Protection Agency's (EPA) cancer risk assessments for PCE and TCE have been withdrawn for the better part of a decade, now, and the cancer risk assessment for chloroform by inhalation is based on an oral study. None of the available epidemiological data suggests that any of these four chemicals represents a realistic cancer hazard at the levels detected.

For example, the highest detected concentration of methylene chloride (6.7 $\mu g/m^3$) exceeded by a factor of 2 the CREG of 3 $\mu g/m^3$, which is ultimately based on inhalation studies in mice exposed 6-hours a day, 5 days a week, for life (104 weeks) to 2,000,000 ppb or 7,000,000 $\mu g/m^3$ methylene chloride. Several more-relevant, epidemiological studies have not detected excess risk of cancer deaths in workers exposed to methylene chloride at levels up to 475,000 ppb or 1,650,000 $\mu g/m^3$ (ATSDR, 1998a).

5.2 Groundwater

Groundwater contamination exists in the Norledge area. The maximum concentrations of some of the compounds detected in this groundwater exceeded EPA's maximum contaminant levels (MCLs) and/or ATSDR's comparison values. These compounds are benzene, bis(2-ethylhexyl)phthalate, ethyl benzene, MTBE, methylene chloride, naphthalene, toluene, and xylenes. However, where there is no exposure, there can be no exposure-related health effects, regardless of the level of environmental contamination. As far as ATSDR has been able to determine, no one is using this contaminated groundwater as a source of drinking water, and no groundwater wells (other than monitoring wells) are located down gradient of the facility. Measures should be taken to assure that this remains the condition, at least until current remediation efforts are effectively completed.

5.3 Soil

To date, subsurface soil sampling in the Norledge area indicated one contaminant, benzene, which was above a health-based comparison value. All other contaminants were below health-based comparison values. In one sample collected at 12 to 14 feet below the ground surface, benzene exceeded ATSDR's CREG comparison value. However, the CREG comparison value is based on chronic (i.e., lifelong) exposure. It is unlikely that chronic exposure occurs because 1) the soil sample was taken at a depth of 12 to 14 feet and 2) only one sample exceeded the CREG value (all other samples were below this health-based comparison value). Therefore, potential intermittent exposures to these subsurface soils during drilling, building, or excavation would be unlikely to result in adverse health effects.

Although exposures to subsurface soil have not indicated contamination at levels of health concern, ATSDR received verbal reports during March 1999 that the city workers had encountered free product (crude oil)

when excavating soil. They were installing new sanitary sewer lines in the Norledge area (ATSDR, 1999b). Precautionary measures should be taken to prevent workers from being exposed to free product during these types of activities.

In the initial public comment version of this public health assessment, ATSDR recommended that samples of surface soil (top 0-3 inches) be collected in the Norledge area to determine if current levels of contaminants are of public health concern. The EPA collected surface soil samples in February 2000. In a May 2000 health consultation, ATSDR determined that the contaminants detected during the surface soil sampling event are not at levels of health concern. No adverse health effects would be expected from exposure to this soil during activities such as gardening or playing.

5.4 Soil Gas

Soil gas contamination exists in the Norledge area; however, concentrations of contaminants contained in soil gas collected from five feet below ground surface generally do not reflect concentrations in the breathing zone. Soil gas measurements are obtained by mechanically evacuating volatiles from the soil using negative pressure and concentrating them in a small, enclosed space for later analysis. Such artificial air concentrations cannot be used for determining the levels that people might actually be exposed to via inhalation of the ambient air. Only measurements in air are directly useful in the assessment of inhalation exposures (see Section 5.1 of this public health assessment).

5.5 Chemical Mixtures

Communities are often concerned about harmful effects that might occur as a result of the combined exposures to more than one chemical present in their environment. Although adverse interactions following exposures to multiple chemicals in our environment are theoretically possible, such effects have been difficult to demonstrate even in well controlled animal experiments, except under conditions where the dose levels of the individual chemicals in the mixture were at or above their respective no-observed effect levels (NOAELs) (Feron et al., 1993; Jonker at el., 1990; Jonker at el., 1993; Groton at el., 1991). Typically, human exposures to most environmental chemicals result in dose levels considerably below their respective NOAELs. For example, at this site, even assuming that the maximum concentrations were always present, the indoor air values are 1 to 5 orders of magnitude (or 10 to 100,000 times) below the lowest known effects levels established in humans or animals. Additionally, the air data indicate that the residents are not constantly exposed to the highest levels of benzene that were found in their homes, but to benzene levels that fluctuate within their homes. Because the individual contaminants detected in media that the residents are directly exposed to have consistently been present at levels below their respective NOAELs, ATSDR considers that the combined effect of all these contaminants is not likely to be of public health concern (see Appendix G for additional information on chemical mixtures). Nevertheless, ATSDR considers it prudent public health policy to reduce or eliminate, wherever possible, excess exposure to substances which at higher concentrations can be toxic.

6. COMMUNITY HEALTH CONCERNS

As part of the petition process, ATSDR staff have gathered health concerns from the petitioner and local community. ATSDR addresses each of the community concerns as follows:

Concern: *Residents are concerned about an increased incidence of cancer in their community, particularly brain cancer, leukemia, and lymphoma.*

Response: At this time, ATSDR is not able to state whether there is increased incidence of brain cancer, leukemia, and lymphoma in Sugar Creek; however, the Missouri Department of Health (MDOH) is conducting an investigation of these cancers in this area. Recently, MDOH added breast cancer to their

investigations. For each phase of their investigation, MDOH releases a report which ATSDR reviews. For information on brain cancer, leukemia, and lymphoma, please refer to Appendix F.

Concern: *Residents are concerned about an increased incidence of Alzheimer's in their community.*

Response: ATSDR was not able to determine whether the incidence of Alzheimer's is higher than expected in Sugar Creek since data regarding this disease are not routinely collected by public health agencies. However, current medical and toxicological literature have not established an association between the types of contaminants identified off-site in the Norledge area and Alzheimer's. For information on Alzheimer's, please refer to Appendix F.

Concern: *Residents are concerned about an increased incidence of multiple sclerosis in their community.*

Response: Data on multiple sclerosis (MS) are not routinely collected by public health agencies. However, MS has not been linked with any of the identified chemicals of concern in the Norledge area. To address this community concern, ATSDR's Division of Health Studies (DHS) is funding a multiple sclerosis (MS) prevalence study through the Jackson County Health Department to determine if higher rates of MS exist in Sugar Creek and Independence. For information on MS, please refer to Appendix F.

Concern: *Residents are concerned about an increased incidence of nervous disorders in their community.*

Response: The term "nervous disorders" has a broad definition that may include a number of different conditions; thus, it is difficult to comment further at this time. However, at the maximum concentrations measured off-site thus far, none of the contaminants detected in the Norledge area would be expected to increase the incidence of conditions affecting the central or peripheral nervous systems.

Concern: *Residents are concerned about high levels of stress among community members from worrying about environmental contamination which they believe has negatively affected their health and has decreased property values.*

Response: Many stressors are associated with living near an area of potential contamination including the specific stressors mentioned in this comment. ATSDR had considered conducting a stress workshop with the residents of the Norledge area. However, based on conversations and meetings with the residents, it appears that a stress workshop would not appropriately address the community's needs at this time.

Concern: *Residents are concerned about past exposures from when the facility was operating.*

Response: ATSDR determined a completed exposure pathway to air existed when the facility was operating. Although no air data exist to determine the extent to which nearby residents were exposed to air contaminants, ATSDR is evaluating the possibility of modeling. In October 2000, the EPA reported to ATSDR there may be groundwater data from the 1960s and 1970s. Although no past exposure to groundwater was identified, ATSDR has requested this data to evaluate its use in modeling past indoor air concentrations. If modeling is feasible, the information it provides may assist in addressing community concern about past indoor air exposures.

7. ATSDR CHILD HEALTH INITIATIVE

ATSDR recognizes that infants and children may be more vulnerable to exposures than adults in communities faced with contamination of their air, water, soil, or food. This vulnerability is a result of the following factors:

- Children are more likely to play outdoors and bring food into contaminated areas.

- Children are shorter, resulting in a greater likelihood of breathing dust, soil, and heavy vapors that are close to the ground.

- Children are smaller, resulting in higher doses of chemical exposure per body weight.

- Children's developing body systems can sustain permanent damage to organs if toxic exposures occur during critical growth stages.

Because children depend completely on adults for risk identification and management decisions, ATSDR is committed to evaluating their special interests at the Amoco Oil Company site, as part of the ATSDR Child Health Initiative.

Children who are the most likely to be exposed to environmental media at the site are those living in nearby homes and attending nearby schools. Indoor air and subsurface soil sampling data do not indicate contaminants at levels of health concern for area children. No exposures to groundwater or soil gas have been identified.

8. CONCLUSIONS

On the basis of available environmental and toxicologic information, ATSDR concludes that the Norledge area, adjacent to the Amoco Oil Company site in Sugar Creek, Missouri, poses a *No Apparent Public Health Hazard.* This determination was made because the levels of contaminants detected during indoor air sampling events are not likely to be associated with adverse health effects for short-term exposures. Potential intermittent exposures to subsurface soils in the Norledge area during drilling, building, and excavating would also be unlikely to result in adverse health effects, although precautionary measures should be taken to prevent worker exposures to free product that may be encountered during these types of activities.

As far as ATSDR has been able to determine, no one is using contaminated groundwater as a source of drinking water. Since the 1920s, Sugar Creek residents have been provided with municipal water. Measures should be taken to assure that residents do not install wells or use contaminated groundwater in the Norledge area for drinking water purposes until current remediation efforts are effectively completed.

Conclusion Update: ATSDR previously concluded in the initial public comment version of this public health assessment that the Amoco Oil Company site in Sugar Creek, Missouri, posed an *Indeterminate Public Health Hazard*[2]. This determination was made because insufficient air data were available to determine whether nearby residents in the Norledge area are chronically exposed to elevated levels of benzene in their homes and no surface soil data (top 0 to 3 inches) were available to determine if surface soil contains contaminants at levels of health concern. However, since this public health assessment was released in May 1999 for public comment, additional indoor air and surface soil sampling data were collected and evaluated. ATSDR determined in subsequent documents that no adverse health effects would be expected from chronic exposure to the levels of contaminants detected in indoor air or surface soil (see Section 5.1 and 5.3).

9. RECOMMENDATIONS

- Prevent potential future exposures to contaminated groundwater, including the placement of institutional controls on the installation of wells in areas of known groundwater contamination.

- Continue remediating contaminated groundwater in the Norledge area.

- Take precautionary measures to prevent worker and resident exposures to free product that may be encountered during drilling, building, and excavating subsurface soil in the Norledge area.

Recommendation Update: ATSDR previously recommended additional indoor air sampling and surface soil sampling in the May 1999 public comment version of this public health assessment. EPA immediately collected the requested data and ATSDR evaluated the data in a March 2000 public health assessment and a May 2000 health consultation. Because the agency's evaluations of the additional data concluded that no adverse health effects would be likely to result from chronic exposure to indoor air or surface soil, ATSDR removed the recommendations to sample indoor air and surface soil from this public health assessment (see Section 5.1 and 5.3).

10. PUBLIC HEALTH ACTION PLAN

The actions described in this section are designed to ensure that this public health assessment identifies public health hazards and provides a plan of action to mitigate and prevent adverse health effects resulting from exposure to hazardous substances in the environment. ATSDR includes a commitment to follow up on this plan and ensure that it is implemented where applicable.

Actions Completed:

- May 3, 1999: ATSDR reviewed and provided comments to the Missouri Department of Health regarding their report entitled, "The Sugar Creek Cancer Inquiry Report - Level 2 Investigation, March 23, 1999."

- May 7, 1999: ATSDR released this public health assessment for public review and comment. ATSDR concluded in the initial public comment version that the Norledge area of Sugar Creek posed an *Indeterminate Public Health Hazard*[3] because only limited data for indoor air was available and no data for surface soil was available.

- May 1999: ATSDR released an easy-to-understand fact sheet summarizing our findings from this public health assessment document. This fact sheet was included as an insert in the Sweet Talk Newsletter released in June1999.

- June 2, 1999: ATSDR conducted a public meeting and public availability sessions during the comment period of this public health assessment to address questions regarding this document and to collect additional community concerns.

- September 1999: ATSDR published an article in the Sweet Talk Newsletter to provide residents with an update on our activities in the Sugar Creek Community.

- March 29, 2000: ATSDR released a public health assessment addendum for public review and comment which evaluated additional air data collected in 1999 in Norledge area homes and health

concerns from community members. ATSDR determined that current, chronic exposures to contaminants in indoor air in Norledge area homes pose *No Apparent Public Health Hazard* to Sugar Creek residents. Current, chronic exposures to the contaminant levels detected are not likely to be associated with adverse health effects.

- April 2000: ATSDR released an easy-to-understand fact sheet summarizing our findings from the March 2000 public health assessment addendum. This fact sheet was included as an insert in the Sweet Talk Newsletter released in May 2000.

- April 12, 2000: ATSDR released a health consultation, "Review of January 2000 Air Data", for public review and comment. ATSDR had received a request on March 10, 2000, from Amoco to review January 2000 indoor air sampling results from eight Amoco-owned homes in the Norledge area. ATSDR determined that the contaminant levels detected during this indoor air sampling event pose *No Apparent Public Health Hazard*.

- May 1, 2000: ATSDR released a health consultation, "Review of February 2000 Soil Data", for public review and comment which evaluated Norledge area surface soil data provided by the EPA. ATSDR determined that the contaminant levels detected during this surface soil sampling event pose *No Apparent Public Health Hazard*. No adverse health effects would be from exposure to this soil during activities such as gardening or playing.

- June 27, 2000: ATSDR reviewed and provided comments to the Missouri Department of Health regarding their report entitled, "The Sugar Creek Cancer Inquiry Report - Level 3 Investigation, March 3, 2000".

- August 28, 2000: ATSDR released a health consultation, "Surface Water and Sediment Data Review", for public review and comment which evaluated surface water and sediment data provided by the Missouri Department of Natural Resources. Based on the limited data provided, ATSDR determined that surface water and sediment contaminants are not a public health threat to residents in the Norledge neighborhood.

Actions Planned:

- ATSDR will continue to assess the health educational needs of the community related to site issues.

- ATSDR will continue to evaluate additional environmental data for the Norledge area for public health significance, upon request. Results of these evaluations will be provided to the public in subsequent ATSDR documents.

- ATSDR will review groundwater data from the 1960s and 1970s to determine the feasibility of modeling indoor air chemical concentrations from this data.

- ATSDR will respond to additional community concerns reported to the agency.

- ATSDR will provide the community with updates about our activities by 1) publishing articles in the Sweet Talk Newsletter for Sugar Creek, 2) developing fact sheets when needed, and 3) providing information to the local television stations, newspapers, and radio stations in the Sugar Creek area.

11. PUBLIC COMMENT

ATSDR released this Amoco Oil Company public health assessment for public review and comment from May 7 through June 20, 1999. Appendix J contains both the comments received during the public comment period and ATSDR's responses to those comments.

12. SITE/TEAM AUTHORS

Environmental Health Scientist:

Danielle M. Langmann, MS
Exposure Investigation and Consultation Branch
Division of Health Assessment and Consultation

Toxicologist:

Frank C. Schnell, PhD, DABT
Exposure Investigation and Consultation Branch
Division of Health Assessment and Consultation

Medical Officer:

David Hewitt, MD, MPH
Exposure Investigation and Consultation Branch
Division of Health Assessment and Consultation

Community Involvement Specialist:

PerStephanie Thompson
Community Involvement Branch
Division of Health Assessment and Consultation

Health Educator:

Teresa Nastoff, RN
Health Education Branch
Division of Health Education and Promotion

Epidemiologist:

Dhelia Williamson, MS
Health Investigation Branch
Division of Health Studies

Regional Representative:

Denise Jordan-Izaguirre

Office of Regional Operations

Writer/Editor:

Kathryn D. Harmsen, MPH
Office of Policy and External Affairs

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[1]The phrase "Indeterminate Public Health Hazard" is a formal conclusion category that ATSDR reserves for sites at which, due to the unavailability of critical information, no determination can be made regarding the existence or non-existence of a potential threat to health in the community.

[2] The phrase "Indeterminate Public Health Hazard" is a formal conclusion category that ATSDR reserves for sites at which, due to the unavailability of critical information, no determination can be made regarding the existence or non-existence of a potential threat to health in the community.

[3] The phrase "Indeterminate Public Health Hazard" is a formal conclusion category that ATSDR reserves for sites at which, due to the unavailability of critical information, no determination can be made regarding the existence or non-existence of a potential threat to health in the community.

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PETITIONED PUBLIC HEALTH ASSESSMENT

AMOCO OIL COMPANY
(a/k/a AMOCO OIL COMPANY - SUGAR CREEK (FINDS) SS#0716)
SUGAR CREEK, JACKSON COUNTY, MISSOURI

APPENDIX A: FIGURES


Figure 1. Amoco Oil Company Site Location Map

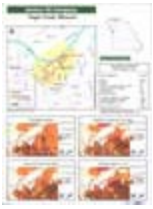


Figure 2. Demographic Statistics


Figure 3. Norledge Area Groundwater Sampling Location Map - 1997

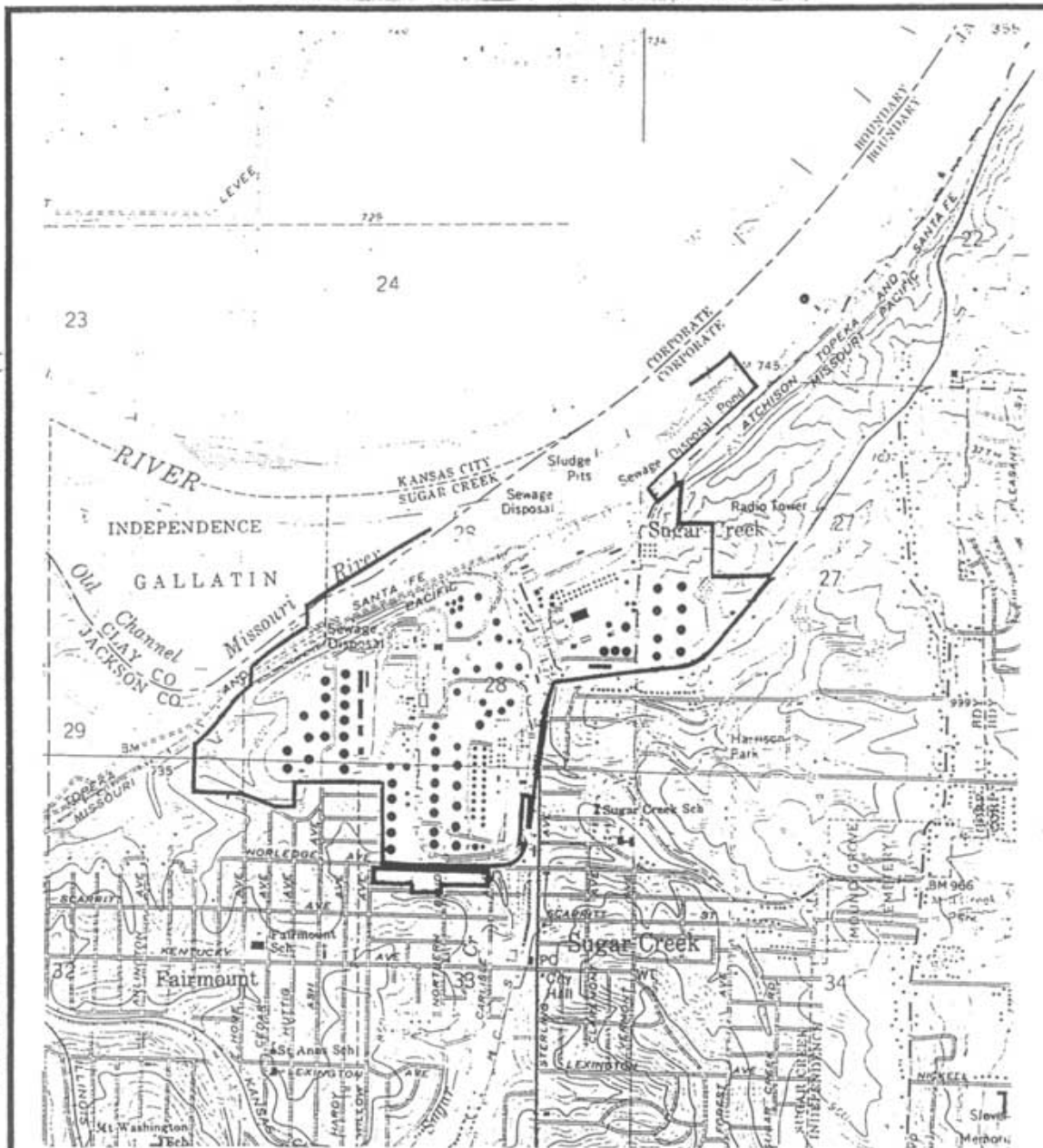

Figure 4. Off-site Groundwater and Soil Sampling Location Map - 1998


Figure 5. Soil Gas Sampling Location Map - 1995


Figure 6. Air Sampling Location Map

APPENDIX B: TABLES

Figure 1: Amoco Oil Company Site Location Map



Reference: Independence & Liberty Quadrangle Maps. USGS 1975

Contour Interval = 10 ft.

TriTechnics CORPORATION
Air, Water and Soil Management

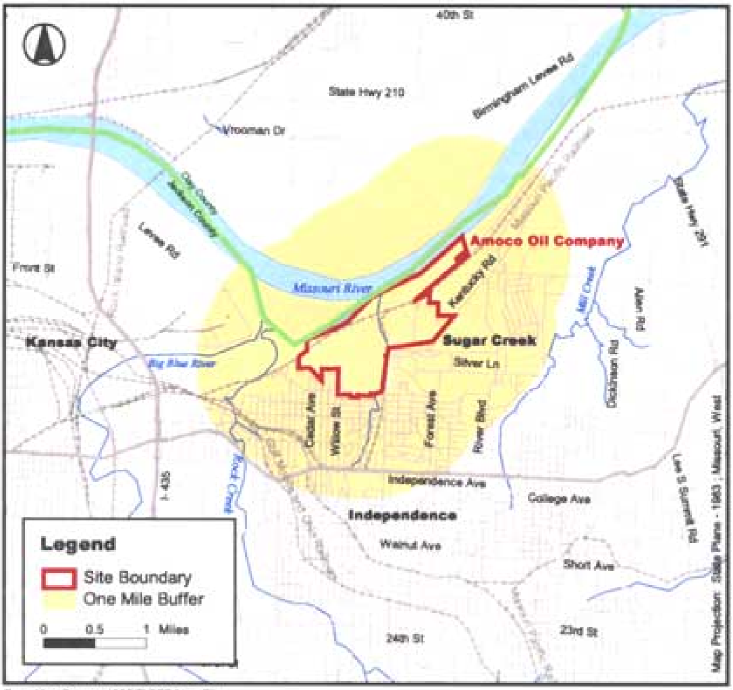
Source: Figure adapted from TriTechnics Corporation, 1995.

Checked By:
Drawn By: ESS
Date: 9/20/95
File Name: 004RF03

Amoco Oil Company

INTRO MAP

Sugar Creek, Missouri



Base Map Source: 1995 TIGER/Line Files

Jackson County, Missouri

Demographic Statistics Within One Mile of Site*	
Total Population	10148
White	9829
Black	43
American Indian, Eskimo, Aleut	73
Asian or Pacific Islander	90
Other Race	113
Hispanic Origin	242
Children Aged 6 and Younger	1119
Adults Aged 65 and Older	1338
Females Aged 15 - 44	2221
Total Housing Units	4468

Demographics Statistics Source: 1990 US Census
*Calculated using an area-proportion spatial analysis technique

Population Density

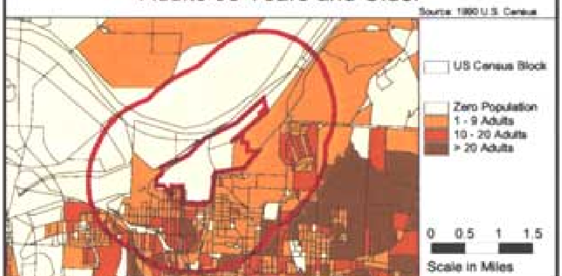
Source: 1990 U.S. Census

Children 6 Years and Younger

Source: 1990 U.S. Census

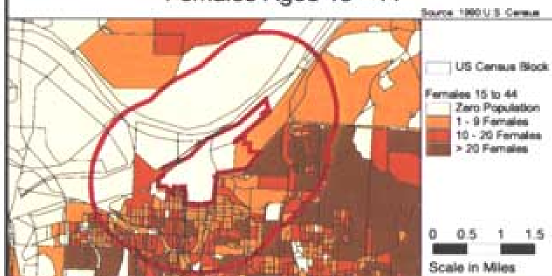
Adults 65 Years and Older

Source: 1990 U.S. Census



Females Aged 15 - 44

Source: 1990 U.S. Census



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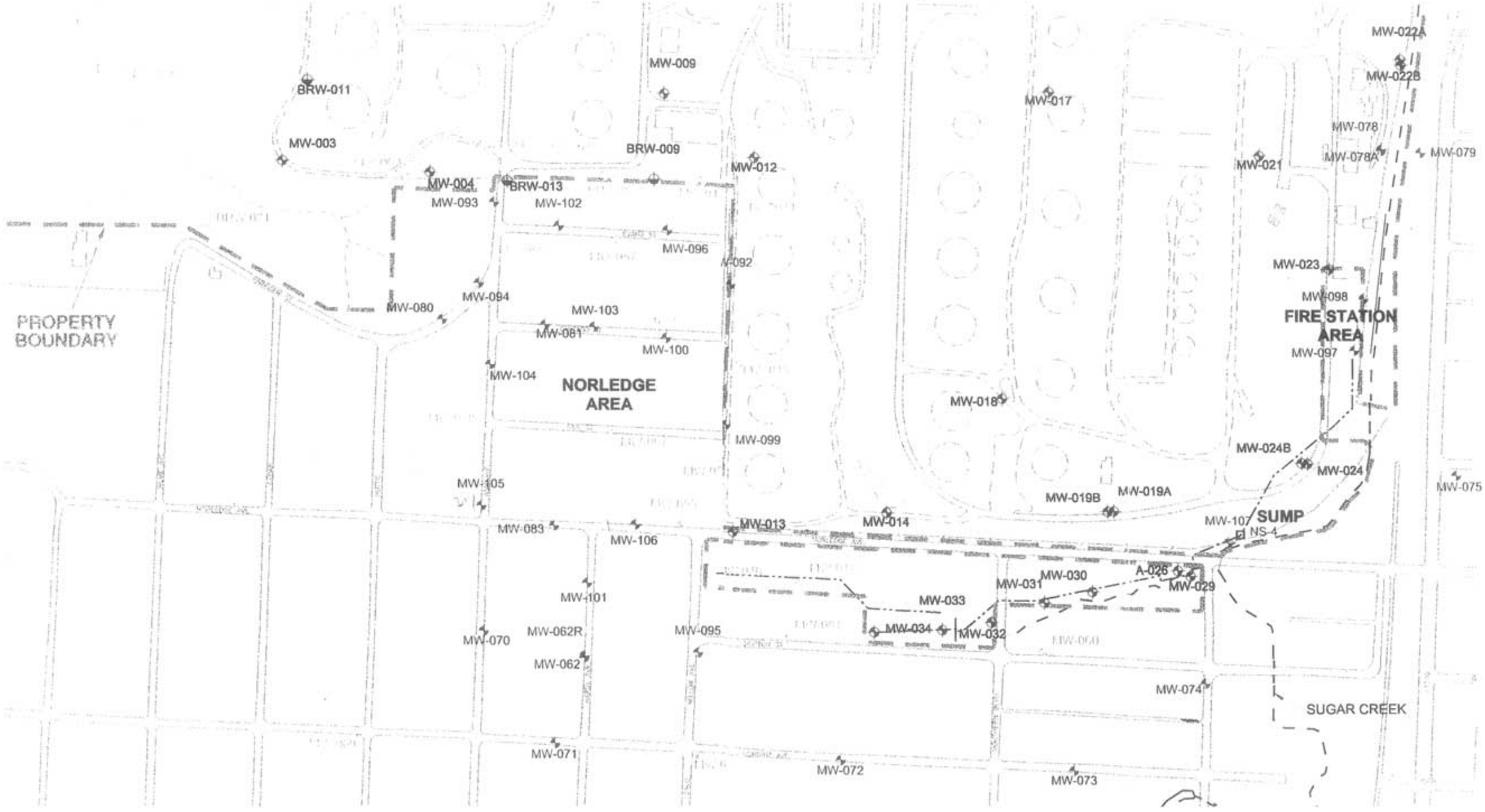
ATSDR SAAGIS

File Name: 00497IN1 Date: 7/17/97 Drawn By: E.S.S. Checked By:



LEGEND

A-049	NON RFI WELL		SHALLOW WELL
			BEDROCK WELL
	WELL INSTALLED FOR RFI, 1990-1992	NS-4	TRENCHSUMP
MW-058R	WELL INSTALLED FOR RFI, 1995		INTERCEPTOR TRENCH
			RETAINING WALLS SURVEYED IN 1997
MW-097	WELL INSTALLED FOR 1997 INVESTIGATION		PROPERTY BOUNDARY

0 300 600

Scale in feet

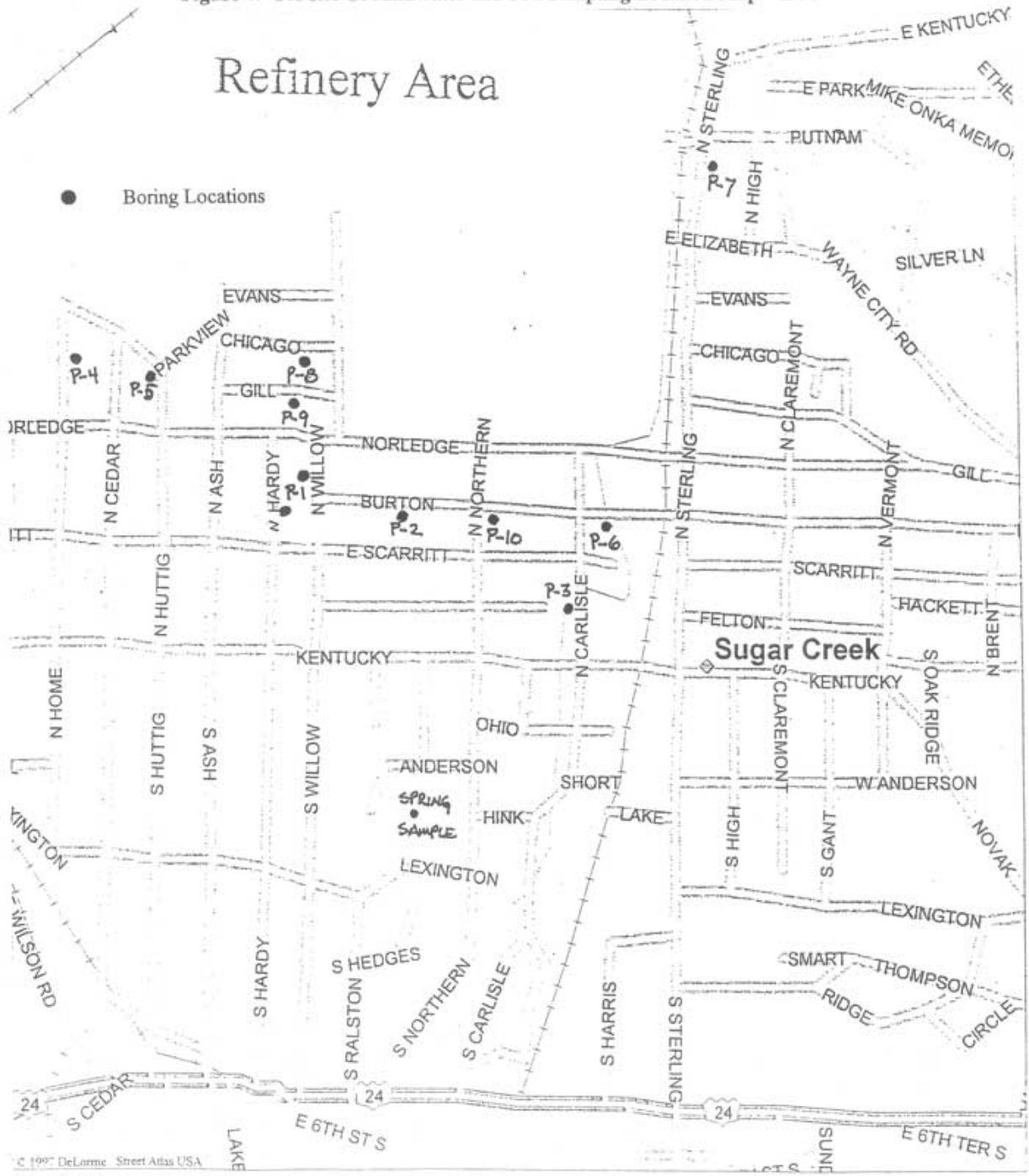
North

TriTechnics CORPORATION
Air, Water and Soil Management
A ENSR COMPANY

Figure 3: Norledge Area Groundwater Sampling Location Map – 1997

Source of Figure: Amoco Oil Company, 1997

Figure 4: Off-site Groundwater and Soil Sampling Location Map – 1998



Source of Figure: Hydro-LOGIC, Inc., 1998.

SC 156163

LEGEND

G-005 SOIL GAS SAMPLE

WGS-002 WATER, GAS, SOIL SAMPLE

NOTE:
ALL SAMPLES COLLECTED IN 1995 BY ECOVA CORPORATION.

0 800 1600

Scale in feet

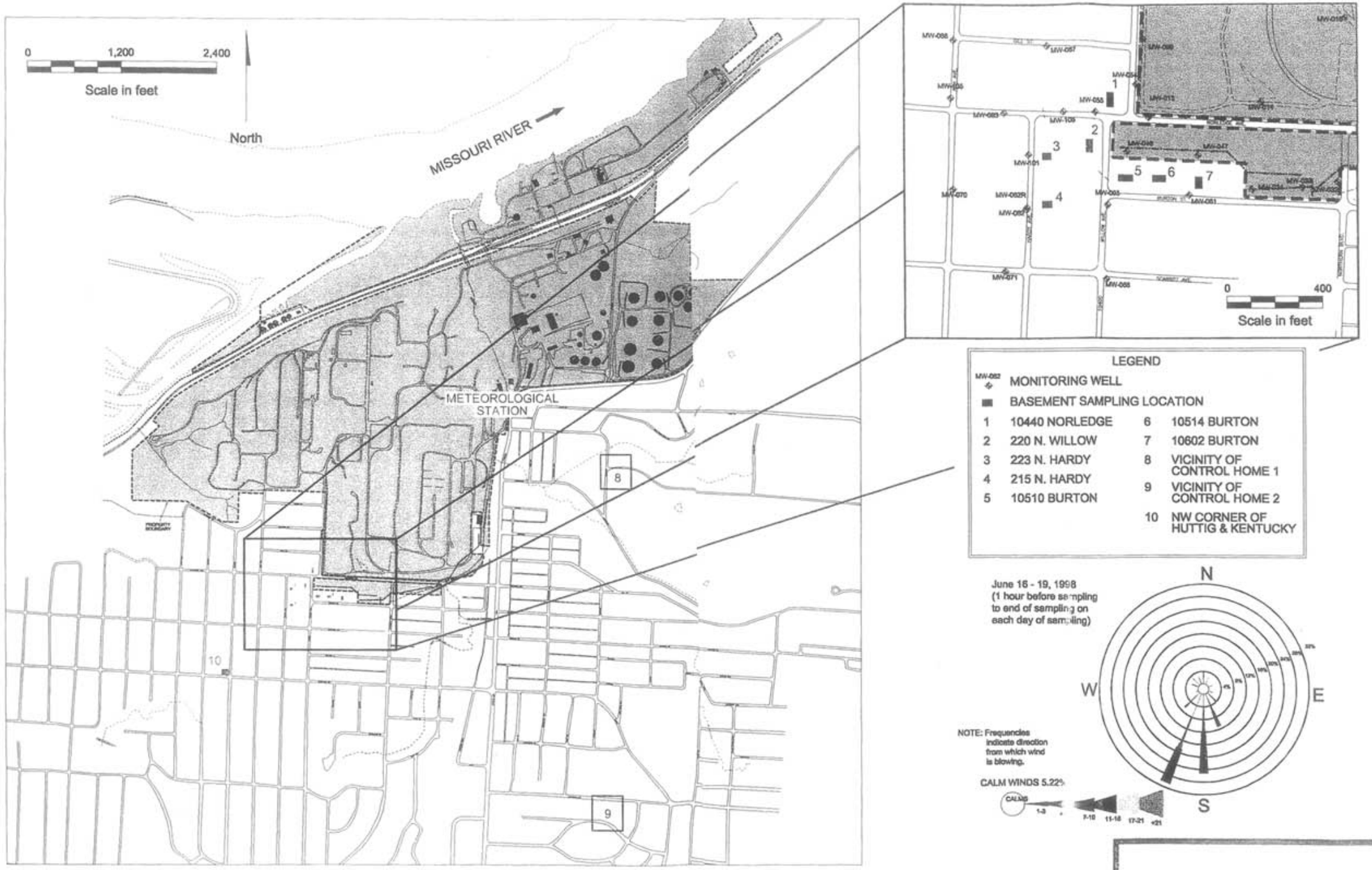
North

Figure 5: Soil Gas Sampling Location Map

TriTechnics CORPORATION
Air, Water and Soil Management

File Name: 004R878 Date: 10/23/95 Drawn By: E.S.S. Chk

Source of Figure: TriTechnics Corporation, 1995.



REMEDIATION TECHNOLOGIES INC

Figure 6: Air Sampling Location Map

Source of Figure: ThermoRetec, 1998

Table 1: Off-site Exposure Pathway Elements

Pathway Name	Exposure Pathway Elements					Time Frame
	Source	Media	Point of Exposure	Route of Exposure	Exposed Population	
Completed Exposure Pathways						
Air (indoor)	Amoco; other sources in the home (e.g., paint cans)	Indoor Air	Residential homes in the Norledge area	Inhalation	People who reside or work in homes in the Norledge area	Past; Current; Future
Potential Exposure Pathways						
Groundwater	Amoco	Private Wells	Norledge area	Ingestion; Inhalation; Dermal	People who may install and use private wells	Future
Soil	Amoco	Subsurface Soil	Norledge area	Dermal	Residents and workers who disturb subsurface soil	Current; Future
Eliminated Exposure Pathways						
Groundwater	Amoco	Private Wells	None	None	None	Past; Current
Soil Gas	Amoco	Soil Gas	None	None	None	Past; Current; Future

Table 2: Off-site Groundwater Sampling Results for the Norledge Area

Compound	Concentration Range (µg/L)	Comparison Value (ppb)		Date of Max. Conc.
Acetone	ND - 160	20,000	IEMEG (child)	3/27/96
		70,000	IEMEG (adult)	
Acenaphthene	ND - 2 J	6,000	IEMEG (child)	2/28/96
		60,000	IEMEG (adult)	
Benzene	ND - 2,560	1	CREG	7/6/98
		5	MCL	
Bis(2-ethylhexyl)phthalate	ND - 88	3	CREG	3/28/96
		6	MCL	
N-butylbenzene	ND - 140	61	RBC(n)	3/28/96
Sec-butylbenzene	ND - 230	61	RBC(n)	3/28/96
Tert-butylbenzene	ND - 3 J	61	RBC(n)	3/28/96
Butylbenzyl phthalate	ND - 2 J	2,000	RMEG (child)	3/28/96
		7,000	RMEG (adult)	
2-Chlorophenol	ND - 2 J	50	RMEG (child)	3/28/96
		200	RMEG (adult)	
4-Chloro-3-methylphenol	ND - 5 J	3,000	Florida	3/28/96

2,4-Dimethylphenol	ND - 66	200	RMEG (child)	3/27/96
		700	RMEG (adult)	
Ethyl benzene	ND - 2,720	1,000	RMEG (child)	5/22/97
		4,000	RMEG (adult)	
		700	MCL	
Isophorone	ND - 12 JD	2,000	Chronic EMEG (child)	3/27/96
		7,000	Chronic EMEG (adult)	
		40	CREG	
Isopropylbenzene (Cumene)	ND - 770	1,000	RMEG (child)	3/28/96
4-Isopropyltoluene (p-Cymene)	ND - 150	A natural plant volatile (100 ppm in fresh, ripe mangos)		3/28/96
Methyl tert butyl ether	ND - 6,160	3,000	IEMEG (child)	4/15/98
		10,000	IEMEG (adult)	
Methylene chloride	ND - 6	2,000	Chronic EMEG (child)	3/26/96
		7,000	Chronic EMEG (adult)	
		5	CREG	
4-Methyl-2-pentanone (Methyl Isobutyl Ketone)	ND - 67	140	RBC(n)	3/26/96
2-Methylnaphthalene	ND - 46	700[a]	Chronic EMEG (child)	3/27/96
		2,000[a]	Chronic EMEG (adult)	
Naphthalene	ND - 569	200	IEMEG (child)	3/29/96
		700	IEMEG (adult)	
Phenol	ND - 4 J	6,000	RMEG (child)	3/27/96
		20,000	RMEG (adult)	
N-propylbenzene	ND - 1,081	61	RBC(n)	3/29/96
Pyrene	ND - 2 J	300	RMEG (child)	3/28/96
		1,000	RMEG (adult)	
Toluene	ND - 1,920	200	IEMEG (child)	12/15/98
		700	IEMEG (adult)	
		1,000	MCL	
1,2,3-Trichlorobenzene	ND - 2 J	100[b]	RMEG (child)	3/28/96
		400[b]	RMEG (adult)	
1,2,4-Trichlorobenzene	ND - 2 J	100	RMEG (child)	3/28/96
		400	RMEG (adult)	
1,2,4-Trimethylbenzene (Pseudocumene)	ND - 2,200 D	12	RBC(n)	3/27/96
1,3,5-Trimethylbenzene				

(Mesitylene)	ND - 802	12	RBC(n)	3/27/96
O-xylene	ND - 1,400 D	12,000	RBC(n)	3/27/96
M,P-xylene	ND - 4,700 D	2,000[c]	IEMEG (child)	3/27/96
		7,000[c]	IEMEG (adult)	
		10,000[c]	MCL	
Xylenes (o, m, p)	ND - 9,010	2,000	IEMEG (child)	12/15/98
		7,000	IEMEG (adult)	
		10,000	MCL	
GRO	ND - 112,000	None		4/15/99
DRO	ND - 206,000 J	None		5/22/97

Sources: Amoco Oil Company, 1997; EnviroRemedy International, Inc., 1996; Hydro-LOGIC, Inc., 1998a; Hydro-LOGIC, Inc., 1998b; Hydro-LOGIC, Inc., 1999; Pace Analytical, 1998c; Pace Analytical, 1999a; Pace Analytical, 1999b; Southwest Laboratories of Oklahoma, Inc., 1999; ThermoRetec, 1999; TriTechnics Corporation, 1996.

a Comparison value is for 1-methylnaphthalene.
b Comparison value is for 1,2,4-trichlorobenzene.
c Comparison value is for total xylenes.

Table Acronyms and Abbreviations:

CREG = Cancer Risk Evaluation Guide
Conc. = Concentration
D = Surrogates or matrix diluted out when sample run at secondary dilution
DRO = Diesel Range Organics
EMEG = Environmental Media Evaluation Guide
GRO = Gasoline Range Organics
IEMEG = Intermediate Environmental Media Evaluation Guide
J = Estimated concentration
Max. = Maximum
MCL = Maximum Contaminant Level
ND = Non-detect
µg/L = micrograms per Liter (equivalent to ppb)
ppb = parts per billion (equivalent to µg/L)
ppm = parts per million
RBC(n) = Risk Based Concentration (noncancer)
RMEG = Reference Dose Media Evaluation Guide

Table 3: Off-site Private Well Sampling Results

Compound	Concentration (µg/L)	Comparison Value (ppb)	
Benzene	617	1	CREG
		5	MCL
Toluene	720	200	IEMEG (child)
		700	IEMEG (adult)
		1,000	MCL
		1,000	RMEG (child)

Ethyl benzene	982	4,000	RMEG (adult)
		700	MCL
Xylenes (o, m, p)	378	2,000	IEMEG (child)
		7,000	IEMEG (adult)
		10,000	MCL
GRO	15,000	None	
DRO	4,070	None	

Source: Hydro-LOGIC, Inc., 1998a.
Date Sampled: July 3, 1998.

Table Acronyms and Abbreviations:

CREG = Cancer Risk Evaluation Guide
DRO = Diesel Range Organics
GRO = Gasoline Range Organics
IEMEG = Intermediate Environmental Media Evaluation Guide
MCL = Maximum Contaminant Level
µg/L = micrograms per Liter (equivalent to ppb)
ppb = parts per billion (equivalent to µg/L)
RMEG = Reference Dose Media Evaluation Guide

Table 4: Off-site Soil Sampling Results

Compound	Concentration Range (mg/kg)	Comparison Value (ppm)		Depth of Max. Conc. (ft)
Benzene	ND - 177	20	CREG	12-14
Toluene	ND - 186	1,000	IEMEG (child)	12-14
		10,000	IEMEG (adult)	
Ethyl benzene	ND - 220	5,000	RMEG (child)	16-18
		70,000	RMEG (adult)	
Xylenes (o, m, p)	ND - 808	10,000	IEMEG (child)	12-14
		100,000	IEMEG (adult)	
2-Methyl naphthalene	1.272	4,000	Chronic EMEG (child)[a]	Unknown
		50,000	Chronic EMEG (adult)[a]	
Methyl tert butyl ether	ND - 0.005	20,000	IEMEG (child)	45-47
		200,000	IEMEG (adult)	
Naphthalene	4.0; 6.384	1,000	IEMEG (child)	Unknown
		10,000	IEMEG (adult)	
GRO	ND - 11,400	None		12-14
DRO	ND - 2,720	None		16-18
TPH	33.1 - 127	None		7.5

Sources: Amoco, 1998; Analytical Report, 1999; EnviroRemedy International, Inc., 1996; Hydro-LOGIC, Inc., 1998a; Hydro-LOGIC, Inc., 1998b; Hydro-LOGIC, Inc., 1999; Southwest Laboratories of Oklahoma, Inc., 1999; ThermoRetec, 1999.

Dates Sampled: July 6 to July 9, 1998; December 15, 1998; December 23, 1998; January 22, 1999; April 15, 1999.

a Comparison value is for 1-Methyl naphthalene.

Table Acronyms and Abbreviations:

Conc. = Concentration
CREG = Cancer Risk Evaluation Guide
DRO = Diesel Range Organics
ft = foot
GRO = Gasoline Range Organics
IEMEG = Intermediate Environmental Media Evaluation Guide
mg/kg = milligrams per kilogram (equivalent to ppm)
ppm = parts per million (equivalent to mg/kg)
RMEG = Reference Dose Media Evaluation Guide
TPH = Total Petroleum Hydrocarbons

Table 5: Off-site Soil Gas Sampling Results

Compound	Concentration Range[a] (µg/m^3)	Location of Max. Conc.	Comparison Value (µg/m^3)[b]	
Benzene	ND - 33,173	G-19	0.1	CREG
			13 (4 ppb)	IEMEG
			160 (50 ppb)	Acute EMEG
Toluene	ND - 31,540	WGS-3	3,800 (1,000 ppb)	Chronic EMEG
			11,000 (3,000 ppb)	Acute EMEG
			400	RfC
Ethyl benzene	ND - 28,684	G-24	870 (200 ppb)	IEMEG
			1,000	RfC
Xylenes	ND - 21,062	G-11	430 (100 ppb)	Chronic EMEG
Total BTEX	ND - 77,400	G-19	None	

Source: TriTechnics Corporation, 1995b.
Date Sampled: March 1995.

a The concentrations of contaminants in soil gas do not generally reflect concentrations in the breathing zone. The measurements are obtained by mechanically evacuating volatiles from the soil.

b The units for the comparison values are in µg/m^3, unless otherwise specified.

Table Acronyms and Abbreviations:

BTEX = Benzene, toluene, ethyl benzene, and xylene
CREG = Cancer Risk Evaluation Guide
EMEG = Environmental Media Evaluation Guide
IEMEG = Intermediate Environmental Media Evaluation Guide
Max. Conc. = Maximum concentration
ND = not detected
ppb = parts per billion
RfC = Reference Concentration
RMEG = Reference Dose Media Evaluation Guide
µ g/m^3 = micrograms of hydrocarbon compound per cubic meter of air

Table 6: Off-site Air Sampling Results (June 1998)

Compound	Indoor Concentration Range ($\mu g/m^3$)	Control Indoor Concentration Range ($\mu g/m^3$)	Comparison Value ($\mu g/m^3$)[a]	
Acetone	ND - 30	ND	31,000 (13,000 ppb)	Chronic EMEG
Acetonitrile	ND - 10	ND	52	RBC(n)
Benzene	ND - 62	6.1 - 120	0.1	CREG
			13 (4 ppb)	IEMEG
			160 (50 ppb)	Acute EMEG
2-Butanone	ND - 5	ND	1,000	RfC
Chloroform	ND - 7.9	ND	0.04	CREG
			98 (20 ppb)	Chronic EMEG
			240 (50 ppb)	IEMEG
			490 (100 ppb)	Acute EMEG
Chloromethane	ND - 1.6	ND	103 (50 ppb)	Chronic EMEG
			410 (200 ppb)	IEMEG
			1,030 (500 ppb)	Acute EMEG
1,4-Dichlorobenzene	ND - 3,400	73	601 (100 ppb)	Chronic EMEG
			1,200 (200 ppb)	IEMEG
			4,800 (800 ppb)	Acute EMEG
Dichlorodifluoromethane	ND - 5.5	5.5	180	RBC(n)
Ethyl benzene	ND - 66	10 - 78	870 (200 ppb)	IEMEG
			1,000	RfC
Methylene Chloride	ND - 4.6	6.7	3	CREG
			104 (30 ppb)	IEMEG
			1,400 (400 ppb)	Acute EMEG
N-Pentane	ND - 8	ND	> 600[b]	Chronic EMEG

Propene	ND - 10	ND	> 30[c]	RfC
Tetrachloroethene	ND	11	2	CREG
			270 (40 ppb)	Chronic EMEG
			1,400 (200 ppb)	Acute EMEG
Toluene	ND - 460	38 - 420	3,800 (1,000 ppb)	Chronic EMEG
			11,000 (3,000 ppb)	Acute EMEG
1,1,1-Trichloroethane	ND - 19	9.4	3,800 (700 ppb)	IEMEG
			10,900 (2,000 ppb)	Acute EMEG
Trichloroethene	ND	4.5	0.6	CREG
			540 (100 ppb)	IEMEG
			10,700 (2,000 ppb)	Acute EMEG
Trichlorofluoromethane	ND - 6.3	7.4	730	RBC(n)
1,2,4-Trimethylbenzene	ND - 100	25	123,000 (25,000 ppb)	TLV
1,3,5-Trimethylbenzene	ND - 90	17	123,000 (25,000 ppb)	TLV
Xylenes	ND - 230	39 - 280	430 (100 ppb)	Chronic EMEG

Source: ThermoRetec, 1998.
Dates Sampled: June 16 to June 19, 1998.

a The units for the comparison values are in $\mu g/m^3$ unless otherwise specified.
b The chronic EMEG for n-Hexane is provided, which is more toxic than pentane.
c The RfC for propylene oxide is provided, which is the active metabolite of propene.

Table Acronyms and Abbreviations:

CREG = Cancer Risk Evaluation Guide
EMEG = Environmental Media Evaluation Guide
IEMEG = Intermediate Environmental Media Evaluation Guide
J = estimated concentration
ND = not detected
ppb = parts per billion
RBC(n) = Risk Based Concentration - noncancer
RfC = Reference Concentration

RMEG = Reference Dose Media Evaluation Guide
μ g/m^3 = micrograms per cubic meter of air

Table 7: Off-site Air Sampling Results (November 1998 & October 1999)

Compound	Concentration Range[a] (ppbv)	Comparison Value (ppb)[b]	
Benzene	ND - 5	0.03 (0.1 μg/m^3)	CREG
		4	IEMEG
		50	Acute EMEG
Toluene	ND - 6.9	1,000	Chronic EMEG
		3,000	Acute EMEG
Ethyl benzene	ND - 1.1	200	IEMEG
Xylenes (M & P)	ND - 3.5	100[c]	Chronic EMEG
Xylenes (O)	ND - 0.95	2,000 (7,300 μg/m^3)	RBC(n)
Chloromethane	ND - 2.5	50	Chronic EMEG
		200	IEMEG
		500	Acute EMEG
1,4-Dichlorobenzene	ND - 16	100	Chronic EMEG
		200	IEMEG
		800	Acute EMEG
Dichlorodifluoromethane	ND - 0.83	40 (180 μg/m^3)	RBC(n)
Styrene	ND - 0.72	60	Chronic EMEG
Trichlorofluoromethane	ND - 2.1	130 (730 μg/m^3)	RBC(n)
1,2,4-Trimethylbenzene	ND - 1.4	25,000	TLV

Source: Pace Analytical, 1998a; Pace Analytical, 1998b; ThermoRetec, 2000.
Date Sampled: November 16, 1998, and October 21-22, 1999.

a Only those contaminants detected are presented in the table.
b The units for the comparison values are in ppb unless otherwise specified.
c Comparison value is for total xylenes.

Table Acronyms and Abbreviations:

CREG = Cancer Risk Evaluation Guide
EMEG = Environmental Media Evaluation Guide
IEMEG = Intermediate Environmental Media Evaluation Guide
ND = not detected
ppb = parts per billion
ppbv = parts per billion volume
RBC(n) = Risk Based Concentration - noncancer
RfC = Reference Concentration
RMEG = Reference Dose Media Evaluation Guide
TLV = Threshold Limit Value
μ g/m^3 = micrograms of hydrocarbon compound per cubic meter of air

APPENDIX C: COMPARISON VALUES

ATSDR comparison values are media-specific concentrations that are considered to be safe under default conditions of exposure. They are used as screening values in the preliminary identification of site-specific "contaminants of concern". The latter term should not be misinterpreted as an implication of "hazard". As ATSDR uses the phrase, a "contaminant of concern" is a chemical substance detected at the site in question and selected by the health assessor for further evaluation of potential health effects. Generally, a chemical is selected as a "contaminant of concern" because its maximum concentration in air, water, or soil at the site exceeds one of ATSDR's comparison values.

However, it must be emphasized that comparison values are not thresholds of toxicity. Although concentrations at, or below, the relevant comparison value may reasonably be considered safe, it does not automatically follow that any environmental concentration that exceeds a comparison value would be expected to produce adverse health effects. The principle purpose behind protective health-based standards and guidelines is to enable health professionals to recognize and resolve potential public health hazards before they become actual public health consequences. For that reason, ATSDR's comparison values are typically designed to be 1 to 3 orders of magnitude (or 10 to 1,000 times) lower than the corresponding no-effect levels (or lowest-effect levels) on which they are based. The probability that such effects will actually occur does not depends on environmental concentrations alone, but on a unique combination of site-specific conditions and individual lifestyle and genetic factors that affect the route, magnitude, and duration of actual exposure.

Listed and described below are the various comparison values that ATSDR uses to select chemicals for further evaluation, as well as other non-ATSDR values that are sometimes used to put environmental concentrations into a meaningful frame of reference.

CREG = Cancer Risk Evaluation Guides
MRL = Minimal Risk Level
EMEG = Environmental Media Evaluation Guides
IEMEG = Intermediate Environmental Media Evaluation Guide
RMEG = Reference Dose Media Evaluation Guide
RfD = Reference Dose
RfC = Reference Dose Concentration
RBC = Risk-Based Concentration
MCL = Maximum Contaminant Level

Cancer Risk Evaluation Guides (CREGs) are estimated contaminant concentrations expected to cause no more than one excess cancer in a million persons exposed over a lifetime. CREGs are calculated from EPA's cancer slope factors, or cancer potency factors, using default values for exposure rates. However, neither CREGs nor cancer slope factors can be used to make realistic predictions of cancer risk. The true risk is always unknown and may be as low as zero.

Minimal Risk Levels (MRL) are estimates of daily human exposure to a chemical (doses expressed in mg/kg/day) that are unlikely to be associated with any appreciable risk of deleterious noncancer effects over a specified duration of exposure. MRLs are calculated using data from human and animal studies and are reported for acute (14 days), intermediate (15-364 days), and chronic (365 days) exposures. MRLs are published in ATSDR Toxicological Profiles for specific chemicals.

Environmental Media Evaluation Guides (EMEGs) are concentrations that are calculated from ATSDR minimal risk levels by factoring in default body weights and ingestion rates.

Intermediate Environmental Media Evaluation Guides (IEMEG) are calculated from ATSDR minimal

risk levels; they factor in body weight and ingestion rates for intermediate exposures (those occurring for more than 14 days and less than 1 year).

Reference Dose Media Evaluation Guide (RMEG) is the concentration of a contaminant in air, water or soil that corresponds to EPA's RfD for that contaminant when default values for body weight and intake rates are taken into account.

Reference Dose (RfD) is an estimate of the daily exposure to a contaminant unlikely to cause noncarcinogenic adverse health effects. Like ATSDR's MRL, EPA's RfD is a dose expressed in mg/kg/day.

Reference Concentrations (RfC) is a concentration of a substance in air that EPA considers unlikely to cause noncancer adverse health effects over a lifetime of chronic exposure.

Risk-Based Concentrations (RBC) are media-specific concentrations derived by Region III of the Environmental Protection Agency from RfD's, RfC's, or EPA's cancer slope factors. They represent concentrations of a contaminant in tap water, ambient air, fish, or soil (industrial or residential) that are considered unlikely to cause adverse health effects over a lifetime of chronic exposure. RBCs are based either on cancer ("c") or noncancer ("n") effects.

Maximum Contaminant Levels (MCLs) represent contaminant concentrations in drinking water that EPA deems protective of public health (considering the availability and economics of water treatment technology) over a lifetime (70 years) at an exposure rate of 2 liters of water per day.

APPENDIX D: METHODOLOGY OF EVALUATING CHEMICALS OF CONCERN

The Agency for Toxic Substances and Disease Registry (ATSDR) has determined levels of chemicals that can reasonably (and conservatively) be regarded as harmless, based on the scientific data the agency has collected in its toxicological profiles. The resulting comparison values and health guidelines, which include ample safety factors (also known as an uncertainty factor) to ensure protection of sensitive populations, are used to screen contaminant concentrations at a site and to select substances (referred to as "chemicals of concern") that warrant closer scrutiny. A "chemical of concern" is defined by ATSDR as any chemical that is detected in air, water, or soil at concentrations exceeding one or more of ATSDR's comparison values. (Refer to Appendix C for a more complete description of ATSDR's comparison values, health guidelines, and other values ATSDR uses to screen site contaminants.)

It is important to understand that comparison values are not thresholds of toxicity. Although concentrations at, or below, the relevant comparison value may reasonably be considered safe, it does not necessarily follow that any concentration that exceeds a comparison value would be expected to produce adverse health effects. Indeed, the principle purpose behind protective health-based standards and guidelines is to enable health professionals to recognize and resolve potential public health problems before that potential is realized. For that reason, ATSDR's comparison values are typically designed to be 1 to 3 orders of magnitude lower than the corresponding no-effect levels (or lowest-effect levels) on which they are based.

When screening individual contaminants, ATSDR staff compare the highest single concentration of a contaminant detected at the site with the lowest comparison value available for the most sensitive of the potentially exposed individuals (usually children or pica children). Typically the cancer risk evaluation guide (CREG) or chronic environmental media evaluation guide (EMEG) is used. This "worst-case" approach introduces a high degree of conservatism into the analysis and often results in the selection of many contaminants as "chemicals of concern" that will not, upon closer scrutiny, be judged to pose any hazard to human health. In the interest of public health, it is prudent to use a screen that identifies many "harmless" contaminants, as opposed to one that may overlook even a single potential hazard to public health. The reader should keep in mind the conservativeness of this approach when interpreting ATSDR's analysis of the

potential health implications of site-specific exposures.

As ATSDR's most conservative comparison value, the CREG, requires special mention. ATSDR's CREG is a media-specific contaminant concentration derived from the chronic (essentially, lifetime) dose of that substance which, according to an Environmental Protection Agency (EPA) estimate, corresponds to a 1-in-1,000,000 cancer risk level. Note, this does not mean that exposures equivalent to the CREG are expected to cause 1 excess cancer case in 1,000,000 ($1x10^{-6}$) persons exposed over a lifetime. Nor does it mean that every person in a population of one million has a 1-in-1,000,000 risk of developing cancer from the specified exposure. Although commonly interpreted in this way, EPA estimates of cancer "risk" are estimates of population risk only and cannot be applied meaningfully to any individual. EPA explicitly stated in it's 1986 Cancer Risk Assessment Guidelines that "The true risks are unknown and may be as low as zero" (EPA, 1986).

Reference:

EPA, 1986. Environmental Protection Agency. Guidelines for Carcinogenic Risk Assessment. Fed. Reg., 51: 33997-33998, September 24, 1986.

APPENDIX E: BENZENE

Benzene (benzol or coal tar naphtha) is a known human carcinogen, and is classified as such by the National Toxicology Program (NTP), the International Agency for Research on Cancer (IARC), the Environmental Protection Agency (EPA), and the American Conference of Governmental Industrial Hygienists (ACGIH).

Benzene is a common solvent isolated from coal tar and crude oil. Although it is naturally released into the atmosphere as an emission of volcanos, forest fires, and even many plants, the primary sources of benzene exposure for the general population are tobacco smoke (50%), automobile service stations, vehicle exhaust and industrial emissions (20%), and vapors from benzene-containing household products such as glues, paints, furniture wax, and some detergents (ATSDR, 1997a). Environmental exposure to benzene has recently been reviewed by the Environmental Protection Agency (EPA) (Wallace, 1996). More than 99% of personal exposure to benzene is through the air, averages about 15 $\mu g/m^3$ (4.7 ppb) and ranges from 7 to 29 $\mu g/m^3$ (2 to 9 ppb). These values reflect the results of EPA's Total Exposure Assessment Methodology (TEAM), a study conducted between 1980 through 1987 using personal air quality monitors to measure direct personal exposures in about 800 persons around the United States. This sample was designed to be representative of the non-occupational exposure of 800,000 people in these areas.

Due partly to the domestic use of household products and partly to home insulation, indoor air concentrations (on the order of 10 $\mu g/m^3$ or 3.1 ppb) typically exceed outdoor air concentrations, which average 6 $\mu g/m^3$ (1.9 ppb) and range from 2 to 19 $\mu g/m^3$ (0.6 to 5.9 ppb). (Note: air concentrations of benzene may be converted from $\mu g/m^3$ to ppb by dividing by 3.2, or from ppb to $\mu g/m^3$ by multiplying by 3.2.) Levels in the city are generally higher than those in rural areas. Average rural background levels of benzene in air historically range from 0.1 to 17 ppb (IARC, 1982). More current figures for the range of average rural background levels in the U.S. are not available. However, since 1986, statewide average levels at about 20 sites throughout California fluctuated between 1.6 and 2.2 ppb until 1993 and 1994 when they dropped to about 1.25 ppb, probably as a result of various actions taken to reduce automobile emissions (Wallace, 1996). Average levels were higher in winter and lower in summer.

In smokers, the benzene in mainstream cigarette smoke overwhelms all other sources combined. The average smoker may be exposed to 10 times as much benzene as is the average non-smoker (Wallace, 1996). For non-smokers, most benzene exposure is ultimately derived from automobile exhaust and gasoline vapor

emissions. No significant effect on personal exposure has been detected in persons living close to major fixed sources of benzene, such as oil refineries, storage tanks, and chemical plants (Wallace, 1996).

The lowest human effect levels reported in ATSDR's recently updated ATSDR Toxicological Profile for Benzene, i.e., 690 ppb for leukopenia (Xia et al.,1995) and 300 ppb for leukemia (Ott et al., 1978), are 36 and 16 times higher, respectively, than the highest level of benzene detected in indoor air in the Norledge area. These values (690 ppb and 300 ppb) represent the lowest measured concentrations in a range of industrial hygiene measurements in each facility in the two studies, which were 690 to 140,000 ppb and 300 to 35,000 ppb, respectively. Use of the lowest measured concentration as an indicator of exposure in the facilities is conservative and will likely underestimate actual exposures. Assuming a normal dose-response relationship in which lower doses are less toxic than higher ones and consistent with the epidemiological and toxicological literature (Paustenbach et al., 1992; Rinsky et al, 1987; Wong, 1995), any adverse effects caused by benzene would be expected to occur in workers exposed to the higher, rather than the lower, end of those exposure ranges. In an update of the Ott study, it was noted that "the workers who died of leukemia had the potential for unquantified, but potentially high, exposures to benzene" (Bond et al., 1986).

ATSDR's benzene cancer risk evaluation guide (CREG) is based primarily on studies of U.S. workers (the Pliofilm cohort) exposed to high levels of benzene (up to hundreds of ppm or hundreds of thousands of ppb) during rubber manufacture, mostly during the 1940s. Like all CREGs, it is based on an EPA-estimated cancer slope factor that, in turn, is based on the assumption that the dose-response relationship is constant with dose (i.e., that the proportion of effects seen at high doses will be the same in the low-dose range where effects are unmeasurable). This is the zero-threshold policy assumption that forms the basis of virtually all quantitative cancer risk estimates in the United States. This zero-threshold assumption allows risk assessors to extrapolate from high-dose animal data into the realm of very low environmental doses. Because no health effects data exist at such low levels of exposure, the resulting quantitative cancer risk estimates are hypothetical. As stated in EPA's 1986 Guidelines on Cancer Risk Assessment, "the true risk is unknown and may be as low as zero" (EPA, 1986).

Available studies indicate no detectable excess of leukemia below cumulative exposures of 40 ppm-years (Rinsky et al, 1987). This would be numerically, if not biologically, equivalent to about 190 ppb, 24 hours a day, over a 70-year lifetime. However, this apparent threshold is most likely an underestimate because it is based on underestimated exposures and the inclusion of all leukemias, not just AML. When only AML is considered, the estimated threshold was found to be at least 200 ppm-years (numerically equivalent to 950 ppb, 24 hours a day, over a 70-year lifetime), based on the original set of exposure estimates, and higher still using later, more accurate exposure estimates (Paustenbach et al., 1992; Wong, 1995). (The notation "ppm-year" represents a numerical attempt to integrate the levels and durations of exposure observed in occupational studies as a product of the two. A worker exposed to 2 ppm for 20 years and one exposed to 20 ppm for 2 years both received the "same" cumulative exposure, i.e., expressed in ppm-years. The distinction is made between numerical and biological equivalence because, although an aspirin a day for 70 years would be numerically equivalent to 70 aspirin a day for 1 year, the two dose rates would produce very different biological effects. The first dose regimen might protect one from cardiovascular disease, while the second would be lethal.)

No unequivocally adverse health effects have been observed in animals or humans chronically exposed to 1,000 ppb (1 ppm) or less of benzene in air. The benzene levels measured in the homes were 1 to 3 orders of magnitude below this level. The air data indicate that the residents are not constantly exposed to the highest levels of benzene that were found in their homes, but to benzene levels that fluctuate within their homes. Therefore, none of the benzene exposures in the Norledge area would be expected to produce any adverse health effects of either a cancerous or non-cancerous nature. Nevertheless, ATSDR considers it prudent public health policy to reduce or eliminate, wherever possible, excess exposure to substances which at higher concentrations can be toxic.

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APPENDIX F: HEALTH ENDPOINTS

Brain Cancer:

The cause of most brain cancer remains largely unknown. It is important to differentiate between primary brain tumors and metastatic tumors that originate from another primary site (e.g., lung). About 25% of people

who die of cancer have brain metastases. Primary brain tumors in children are associated with certain underlying diseases, including neurofibromatosis, tuberous sclerosis, and von Hippel-Lindau angiomatosis. Family clusters of central nervous system (CNS) tumors have been reported. High-dose ionizing radiation may cause brain cancer in humans and certain alkylating agents, especially nitrosamides, are effective neurocarcinogens in laboratory animals; in humans, however, the data are mixed and inconclusive (Inskip, et al., 1995).

Leukemia:

The only contaminant of concern identified so far at Amoco/Sugar Creek is benzene, and the only specific cancer consistently seen in excess among benzene-exposed workers is acute myelogenous leukemia (AML). However, benzene-induced AML exhibits a relatively high threshold; it is only seen in workers who have experienced prolonged, high-level exposure, i.e., >200 ppm-years (Wong, 1995). The known risk factors for leukemia include radiation, benzene, alkylating drugs, myelodysplastic syndromes, and hereditary syndromes such as Franconi's aplasia and Down's syndrome (Casciato & Lowitz, 1988).

Lymphoma:

Viral etiology and immunodeficiency states are strongly associated with the development of lymphomas. To date, however, no exposures to chemicals in the environment are known to cause lymphomas in humans. Notwithstanding some suggestive early studies, the weight of evidence for a link between non-Hodgkin's lymphoma and organochlorines is weak and inconsistent. The histologic diagnoses for reported lymphoma is unknown (Merck, 1992a).

Alzheimer's:

The etiology of Alzheimer's disease remains unknown in spite of intensive research efforts. Recent studies of genetic linkage in familial Alzheimer's disease have focused on the genes for amyloid precursor protein (APP) and apolipoprotein E (Drouet et al., 2000). Several risk factors of Alzheimer's disease have been revealed by epidemiological studies, including age, family history, head trauma, thyroid dysfunctions, and aluminum (Al) (Chang & Dyer, 1995). Although genetic and other biological factors are important in Alzheimer's disease, environmental factors could also contribute to its development. The most studied of these are aluminum, zinc, foodborne poisons, and viruses.

Multiple Sclerosis:

Multiple sclerosis (MS) is an autoimmune disease of unknown etiology. It is generally believed that the inflammation and demyelination observed in MS are caused by microbe-activated T-cells which cross the blood-brain barrier and cross-react with myelin proteins. MS appears to be the result of a complex interaction between multiple genetic susceptibility factors and various environmental triggers, including viral infections. Interestingly, incidence increases with latitude away from the equator (e.g., from Queensland to Tasmania, Australia), and risk is reduced by migration from a high MS prevalence area to a low prevalence area before (but not after) puberty (Merck 1992b). This pattern is not consistent with industrial emissions as a causative agent. In any case, because natural, non-specific triggers are ubiquitous in the environment, the availability of man-made triggers would probably not be a limiting or determining factor in the incidence of MS.

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APPENDIX G: CHEMICAL MIXTURES

Since the individual contaminants detected at this site have consistently been present well below levels that might be expected to result in adverse health effects, ATSDR considers that the combined effect of all these contaminants is not likely to be of public health concern either. This conclusion is based on studies which suggest that a mixture produces no adverse health effects in dosed animals when the components of that mixture are present at levels below their respective no-observed-adverse-effect levels (NOAEL), i.e., at concentrations that would have produced no adverse effects in animals treated separately with those component chemicals (Feron et al., 1993; Jonker at el., 1990; Jonker at el., 1993; Groton at el., 1991). In two of these experiments, all of the component chemicals affected the same target organ, albeit through different mechanisms. In two others, the chemicals had different target organs and exhibited different modes of action, as do most chemicals in typical environmental mixtures.

Considering that ATSDR comparison values are typically 10-1000 times lower than their corresponding NOAELs, it is reasonable to expect that environmental contaminants will not produce any combined effects, even if their individual concentrations exceed their respective EMEGs by a significant fraction of the associated safety factor (which ATSDR refers to as a composite "uncertainty factor"). However, in the Norledge area, with the sole exception of benzene, all of the air contaminants detected so far have been present at levels below ATSDR's EMEGs, making interactive effects extremely unlikely. It should be noted, however, that allergic reactions and psychogenic responses to nuisance gasses are not dose-related, and that health-based comparison values are not (and cannot be) designed to prevent responses in hypersensitive individuals.

The same principles described above for the interaction of non-carcinogens may apply to carcinogens, as well. Due to the prevalence of the regulatory assumption of zero-threshold for chemical carcinogens, one does not usually discuss the latter in terms of their NOAELs. Nevertheless, it seems almost certain, based on empirical evidence and established pharmacological principles, that thresholds of effect will exist for carcinogens, as well as for non-carcinogens (Williams and Weisburger, 1991). Available data suggest that even some genotoxic carcinogens (and not just nongenotoxic carcinogens like dioxin and arsenic) do exhibit thresholds, and often at rather high dose levels, relative to typical, environmentally relevant, human exposures (SOT, 1981; Cunningham, 1994). A significant number of thyroid tumors and neoplastic liver nodules were seen in rats exposed for 102 weeks (roughly equivalent to a rat's lifespan) to a mixture of 40 different carcinogenic compounds that targeted different organs (including, liver, thyroid, skin, and urinary bladder) at 1/50 of the doses at which each of the individual chemicals would have produce tumors in 50% of the exposed animals (Takayama et al., 1989). Adopting the regulatory assumption of linearity (solely for the purpose of dose perspective, since the true risk in humans would be unknown and could be as low as zero) the chronically administered dose of each one of these 40 carcinogens was, equivalent to an estimated "risk" of 1/50 X 0.50 = 10^{-2}, i.e., a risk level 10,000 times higher than that (10^{-6}) on which ATSDR's CREGs are usually based. However, when Hasegawa et al. (1994) administered 10 carcinogenic heterocyclic amines in

combination to rats at 1/100 of the doses known to be carcinogenic individually, the effects did not differ significantly from controls (Hasegawa et al., 1994). These doses were 100 times lower than established cancer effect levels, not the NOAELs (which were unknown). ATSDR's CREGs, and the environmental levels of exposure that humans encounter, are typically much lower, still, by many orders of magnitude. These results suggest that mixed exposures to carcinogens at levels that exceed their respective CREGs, but are well below all known effects levels, will not pose any realistic carcinogenic risk.

The aforementioned research findings, in combination with the fact that ATSDR's comparison values are typically 10-1000 times lower than the corresponding NOAELs, suggest that environmental contaminants should not be expected to produce combined effects, even if their individual concentrations exceed their respective EMEGs by a significant fraction of the associated safety factor (also known as an uncertainty factor). Considering how much lower CREGs and environmental exposures usually are, compared to the doses used by Hasegawa et al (1994), a similar argument is probably applicable to carcinogens, as well.

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APPENDIX H: GLOSSARY OF TERMS

Absorption:

The process of taking in, as when a sponge takes up water. Chemicals can be absorbed through the skin into the bloodstream and then transported to other organs. Chemicals can also be absorbed into the bloodstream after breathing or swallowing.

Acute:

Occurring over a short time, usually a few minutes or hours. For purposes of health assessment, ATSDR defines acute exposures as those lasting up to two weeks. An acute exposure can result in short- or long-term health effects.

Ambient:

Surrounding. For example, *ambient* air is usually outdoor air (as opposed to indoor air).

Carcinogen:

Any substance that may produce cancer.

Chronic:

Occurring over a long period of time (more than 1 year).

Comparison Values:

Estimated contaminant concentrations in specific media that are not likely to cause adverse health effects, given a standard daily ingestion rate and standard body weight. The *comparison values* are calculated from the scientific literature available on exposure and health effects.

Concentration:

The amount of one substance dissolved or contained in a given amount of another. For example, sea water contains a higher concentration of salt than fresh water.

Contaminant:

Any substance or material that enters a system (e.g., the environment, human body, food, etc.) where it is not normally found.

Dermal:

Referring to the skin. *Dermal* absorption means absorption through the skin.

Dose:

The amount of substance that actually enters the body over a specified period of time. Dose is expressed in terms of unit weight of chemical per unit body weight per unit of time, e.g., mg/kg/day.

Epidemiology:

The study of the occurrence of disease in human populations and the factors associated with the frequency and distribution of that disease.

Exposure:
Contact with a chemical by swallowing, breathing, or direct contact (such as through the skin or eyes). *Exposure* may be short term (acute) or long term (chronic).

Hazard:
A possible source of danger or harm (i.e., in this context, adverse health effects).

Health Outcome Data:
Information on the prevalence of death, disease or other health-related factors in the community. Such information may be derived from local, state, and national databases, medical records, tumor and disease registries, and health studies.

Indeterminate Public Health Hazard:
A formal conclusion category that ATSDR reserves for sites at which, due to the unavailability of critical information, no determination can be made regarding the existence or non-existence of a potential threat to health in the community.

Ingestion:
Swallowing (such as eating or drinking). Chemicals can get in or on food, drink, utensils, cigarettes, or hands, from which they can be ingested. After *ingestion*, chemicals can be absorbed into the blood and distributed throughout the body.

Inhalation:
Breathing. Exposure may occur from inhaling contaminants, because the contaminants can be deposited in the lungs, taken into the blood, or both.

Media (Environmental):
Soil, water, air, plants, animals, or any other parts of the environment that can contain contaminants.

Petitioned Public Health Assessment:
A public health assessment conducted at the request of a member of the public. When a petition is received, a team of environmental and health scientists is assigned to gather information to ascertain, using standard public health criteria, whether there is a reasonable basis for conducting a public health assessment. Once ATSDR confirms that a public health assessment is needed, the *petitioned health assessment* process is essentially the same as the public health assessment process.

Public Health Action:
As used in ATSDR public health advisories, public health assessments, and health consultations, this term refers to activities designed to prevent exposures and/or to mitigate or prevent adverse health effects in populations living near hazardous waste sites or releases. These actions may include eliminating immediate exposures (e.g., by providing an alternative water supply), monitoring indicators of exposure in bodily fluids (e.g., blood and urine) to better assess exposure, and providing health education for health care providers and community members.

Public Health Hazard:

A formal conclusion category that ATSDR reserves for sites at which chronic, long-term exposure (>1 year) to potentially hazardous contaminants may cause illness in the community.

Route of Exposure:

The way in which a person may contact a chemical substance. The primary routes of exposure are ingestion (as in eating or drinking), inhalation (as in breathing), and dermal or skin contact (as in bathing).

Toxicological Profile:

An ATSDR reference document that identifies and reviews key, peer-reviewed literature describing the properties of a hazardous substances, the levels of significant exposure to that substance, and the associated acute, subacute (intermediate), and chronic health effects in laboratory animals and humans, where known. Toxicological Profiles also describe the experimental and/or epidemiological bases of ATSDR's existing comparison values for the substance, and identify knowledge gaps and research needs.

APPENDIX I: CANCER CLASSIFICATIONS

For the five chemicals exceeding their respective cancer risk evaluation guide (CREG) comparison values, ATSDR describes the various cancer classifications of the National Toxicology Program (NTP), the International Agency for Research on Cancer (IARC), the Environmental Protection Agency (EPA), and the American Conference of Governmental Industrial Hygienists (ACGIH) in the table below. The differences between the classifications for individual substances reflects differences in the parent organization's definitions and methodologies.

Cancer Classifications for Air Chemicals

Chemical	NTP	IARC	EPA	ACGIH
Benzene	Known to be a carcinogen	1 - Carcinogenic to humans	A - Known human carcinogen	A1 - Confirmed human carcinogen
Methylene Chloride	Reasonably anticipated to be a carcinogen	2B - Possibly carcinogenic to humans	B2 - Probable human carcinogen	A3 - Confirmed animal carcinogen
Tetrachloroethene	Reasonably anticipated to be a carcinogen	2A - Probably carcinogenic to humans	Not available at this time	A3 - Confirmed animal carcinogen
Trichloroethene	Not listed by NTP[a]	2A - Probably carcinogenic to humans	Under review	A5 - Not suspected as a human carcinogen
Chloroform	Reasonably anticipated to be a carcinogen	2B - Possibly carcinogenic to humans	B2 - Probable human carcinogen	A3 - Confirmed animal carcinogen

a If NTP approves committee recommendations, the 9th Report on Carcinogens will list TCE as "Reasonably Anticipated to be a Human Carcinogen".

Cancer classifications are useful for determining which regulatory practices are, by policy, most appropriately applied to a given substance. However, they were not designed for, and cannot be used in, the prediction of human cancer incidence rates under various conditions of exposure. Even substances classified by EPA, IARC, NTP, or ACGIH as "known" human carcinogens are known to cause cancer in humans only under the conditions specified in the studies on which those classifications are based. With rare exceptions, a substance is classified by these agencies as a "known" human carcinogen only if there is "sufficient" evidence of carcinogenicity in humans.

EPA classifies a substance as a "probable" (B1 or B2) human carcinogen on the basis of what that agency considers to be "sufficient" evidence of carcinogenicity in animal studies and either "limited" (B1) or "inadequate" (B2) evidence in humans. EPA classifies a substance as a "possible" (C) human carcinogen if the animal evidence is "limited" and no human data are available.

IARC classifies a substance as a "probable" (2A) human carcinogen if the animal evidence is judged to be "sufficient" and the available human evidence is "limited". That agency classifies a substance as a "possible" (2B) human carcinogen if the animal evidence is less than sufficient and/or human data are "limited".

NTP's classification of a substance as "reasonably anticipated to be a carcinogen" may indicate only that the substance does cause cancer in one or more species of laboratory animal under some set of exposure conditions.

The ACGIH classification "confirmed animal carcinogen" with unknown relevance to humans (A3) indicates that an agent is carcinogenic in experimental animals at a relatively high dose, by route(s) of administration, at site(s), of histological types(s), or by mechanism(s) that may not be considered relevant to worker exposures. Additionally, ACGIH's A3 designation indicates that 1) available epidemiologic studies do not confirm an increased risk of cancer in exposed humans, and 2) available evidence suggests that the agent is not likely to cause cancer in humans except under uncommon or unlikely routes or levels of exposure (ACGIH, 1998).

ACGIH classifies as "not suspected as a human carcinogen" (A5), any agent which is not suspected to be a human carcinogen on the basis of properly controlled epidemiological studies in humans. These studies have sufficiently long follow-up, reliable exposure histories, sufficiently high dose, and adequate statistical power to conclude that exposure to the agent does not convey a significant risk of cancer to humans; or, the evidence suggesting a lack of carcinogenicity in experimental animals is supported by mechanistic data (ACGIH, 1998).

More so than those of EPA, IARC, and NTP, ACGIH's cancer classifications address the issue of human relevance, i.e., the likelihood that a substance demonstrated to be carcinogenic in animal studies will also be carcinogenic to humans under realistic conditions of worker exposure (8 hours a day, 40 hours a week). As a result, they are more informative and provide more perspective on the "possible" and "probable" human carcinogens identified by EPA, IARC, and NTP. Thus, ACGIH's cancer categories complement, rather than contradict, those of other agencies.

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PETITIONED PUBLIC HEALTH ASSESSMENT

AMOCO OIL COMPANY
(a/k/a AMOCO OIL COMPANY - SUGAR CREEK (FINDS) SS#0716)
SUGAR CREEK, JACKSON COUNTY, MISSOURI

APPENDIX J: PUBLIC COMMENTS

ATSDR released the Amoco Oil Company public health assessment for public review and comment from May 7, 1999, through June 20, 1999. Each comment received was logged and became part of the administrative record. This appendix contains both the comments received during the public comment period and ATSDR's response to those comments. The comments have been numbered with the response directly below each comment.

Comment 1: In the initial public health assessment, ATSDR relied heavily on Amoco's RCRA Facility Investigation report (RFI). EPA relied on Amoco's 1995 RFI and 1997 Additional Investigation materials in implementing ATSDR's recommendation to sample indoor air in the Norledge area for chronic levels of benzene. Neither document presents an accurate picture of the soil and groundwater contamination conditions in the neighborhood, or the Amoco source areas immediately up gradient from the private residences.

Response 1: In preparing public health assessments, ATSDR gathers available environmental data from the Environmental Protection Agency (EPA), other government agencies, businesses, and the public. ATSDR did not rely heavily on the 1995 RFI. The only environmental data used from the 1995 RFI in ATSDR' evaluation were for the soil gas medium. Other environmental data sources for this document included Amoco's May 1997 Additional Investigation report; Hydro-LOGIC, Inc.'s, 1998 Limited Subsurface Investigation Results report; ThermoRetec Consulting Corporation's 1998 Basement Air Sampling report; and Amoco's 1998 Sampling Protocol and Sampling Results for the Sewer Excavation. Additional data supplied during the public comment period has been also been incorporated (see Comments 2 through 13 and Comment 67). ATSDR's conclusions and recommendations are based on these available data.

Comment 2: We respectfully request that the ATSDR consider the reference document, Affidavit of Mohammed Aboudah, P.E., June 26, 1996, in making the determinations to be included in the final public health assessment. (Document provided by commentor.)

Response 2: ATSDR thanks the commentor for providing additional groundwater data for the Norledge area. A short description of the sampling event was added to Section 4.1. A variety of VOCs and SVOCs were added to Table 2, Appendix B. Some of these contaminants exceeded health-based comparison values; however, as discussed in Section 5.2 of this public health assessment, where there is no exposure, there can be no exposure-related adverse health effects. Therefore, because there is no exposure to Norledge area groundwater, there are no changes to the conclusions of the final public health assessment.

Of note, the commentor mentioned that the laboratory which analyzed the groundwater samples was decertified in 1996. ATSDR has chosen to include the data in this report because 1) quality control/quality assurance procedures appeared to be followed and 2) split samples collected and analyzed at a different laboratory yielded contaminant concentrations in the same ranges (see Comment and Response 3).

Comment 3: We respectfully request that the ATSDR consider the reference document, Analytical

Summary for Split Sampling Results, August 30, 1996, in making the determinations to be included in the final public health assessment. (Document provided by commentor.)

Response 3: ATSDR thanks the commentor for providing additional groundwater data for the Norledge area. A short description of the sampling event was added to Section 4.1 and the additional data are contained in Table 2, Appendix B. The groundwater data in this report are the split samples mentioned in the previous comment (see Comment and Response 2).

Comment 4: We respectfully request that the ATSDR consider November 1998 air sampling data collected by Compass Environmental and analyzed by Pace Analytical from two homes in the Norledge area in making the determinations to be included in the final public health assessment. (Document provided by commentor.)

Response 4: ATSDR thanks the commentor for providing additional air data for the Norledge area. A short description of the sampling event was added to Section 4.4 and the additional data are contained in Table 7, Appendix B. Overall, the contaminants detected in air during this sampling event were either within the same ranges as the air data previously provided in the public comment version of this document and/or below health-based comparison values. Therefore, there are no changes to the conclusions of the final public health assessment.

Comment 5: We respectfully request that the ATSDR consider November 1998 air sampling data collected by Remediation Technologies, Inc., and analyzed by Pace Analytical from two homes in the Norledge area in making the determinations to be included in the final public health assessment. (Document provided by commentor.)

Response 5: ATSDR thanks the commentor for providing additional air data for the Norledge area. A short description of the sampling event was added to Section 4.4 and the additional data are contained in Table 7, Appendix B. Overall, the contaminants detected in air were either within the same ranges as the air data previously provided in the public comment version of this document and/or below health-based comparison values. Therefore, there are no changes to the conclusions of the final public health assessment.

Comment 6: We respectfully request that the ATSDR consider Hydro-LOGIC's December 1998 Addendum to the Limited Subsurface Investigation report in making the determinations to be included in the final public health assessment. (Document provided by commentor.)

Response 6: ATSDR thanks the commentor for providing additional environmental data for the Norledge area. Additional groundwater and subsurface soil sampling results were included in the Addendum Limited Subsurface Investigation report. A short description of the groundwater sampling event was added to Section 4.1 and the contaminant data were included in Table 2, Appendix B. Two contaminants, toluene and xylene, detected during this December 1998 sampling event had maximum values that were above the maximum values reported in the public comment version of this document. However, there are no changes to the conclusions of this final public health assessment because residents are not exposed to Norledge area groundwater. Where there is no exposure, there can be no adverse health effects, regardless of the level of environmental contamination.

A short description of the soil sampling event was added to Section 4.2 and the contaminant data were included in Table 4, Appendix B. All contaminants were detected below the maximum values reported in the public comment version of this document. Therefore, there are no changes to the conclusions of the final public health assessment.

Comment 7: We respectfully request that the ATSDR consider December 1998 Norledge area groundwater sampling data collected by Compass Environmental and analyzed by Pace Analytical in making the determinations to be included in the final public health assessment. (Document provided by commentor.)

Response 7: ATSDR thanks the commentor for providing additional groundwater data for the Norledge area. A short description of the sampling event was added to Section 4.1. One contaminant, methyl tert butyl ether (MTBE), which had not been previously analyzed for in groundwater, was detected during this sampling event. The maximum value of MTBE detected was below health-based comparison values. With the exception of total xylenes, the other contaminants detected in groundwater during this sampling event were in the same ranges as the groundwater data previously provided in the public comment version of this document. There are no changes to the conclusions of this final public health assessment because residents are not exposed to Norledge area groundwater.

Comment 8: We respectfully request that the ATSDR consider December 1998 Norledge area groundwater and soil sampling data collected by ThermoRetec and analyzed by Southwest Laboratory of Oklahoma, Inc., in making the determinations to be included in the final public health assessment. (Document provided by commentor.)

Response 8: ATSDR thanks the commentor for providing additional groundwater and soil data for the Norledge area. A short description of the groundwater sampling event was added to Section 4.1 and the contaminant data are contained in Table 2, Appendix B. MTBE was detected during this sampling event below health-based comparison values. All other contaminants, with the exception of total xylenes, detected in groundwater during this sampling event were in the same ranges as the groundwater data previously provided in the public comment version of this document. There are no changes to the conclusions of this final public health assessment because residents are not exposed to Norledge area groundwater.

A short description of the soil sampling event was added to Section 4.2 and the contaminant data were included in Table 4, Appendix B. One contaminant, MTBE, which had not been previously analyzed for in soil, was detected during this sampling event. The maximum value of MTBE was below health-based comparison values. All other contaminants were detected below health-based comparison values too. Therefore, there are no changes to the conclusions of the final public health assessment.

Comment 9: We respectfully request that the ATSDR consider a January 22, 1999, Norledge area soil sample in making the determinations to be included in the final public health assessment. (Data sheet provided by commentor.)

Response 9: ATSDR thanks the commentor for providing additional soil data for the Norledge area. Three contaminants (toluene, ethylbenzene, and xylenes) in this subsurface soil sample had maximum values above those reported in the public comment version of this document. However, these maximum values were below health based comparison values. Therefore, there are no changes to the conclusions of the final public health assessment.

Comment 10: We respectfully request that the ATSDR consider March 1999 Norledge area water sampling data collected by Compass Environmental and analyzed by Pace Analytical in making the determinations to be included in the final public health assessment. (Document provided by commentor.)

Response 10: ATSDR thanks the commentor for providing additional groundwater data for the Norledge area. A short description of the sampling event was added to Section 4.1 and the contaminant data are contained in Table 2, Appendix B. Overall, the contaminants detected in groundwater were in the same ranges as the groundwater data previously provided in the public comment version of this document. Therefore, there are no changes to the conclusions of the final public health assessment.

Comment 11: We respectfully request that the ATSDR consider Hydro-LOGIC's April 1999 Limited Subsurface Investigation report in making the determinations to be included in the final public health assessment. (Document provided by commentor.)

Response 11: ATSDR thanks the commentor for providing additional environmental data for the Norledge area. Additional groundwater and subsurface soil sampling results were included in the Limited Subsurface Investigation report. A short description of the groundwater sampling event was added to Section 4.1 and the contaminant data were included in Table 2, Appendix B. One sample showed MTBE above a health-based comparison value in groundwater. Also, toluene and total xylenes were detected above the maximum values previously provided in the public comment version of this document. However, there are no changes to the conclusions of this final public health assessment because residents are not exposed to Norledge area groundwater. Where there is no exposure, there can be no adverse health effects, regardless of the level of environmental contamination.

A short description of the soil sampling event was added to Section 4.2 and the contaminant data were included in Table 4, Appendix B. All contaminants, with the exception of benzene, were detected below health-based comparison values. Benzene exceeded the cancer risk evaluation guide (CREG) comparison value in one sample. Clarification of the public health implications of potential exposure to subsurface soil is described in Section 5.3. There are no changes to the conclusions of the final public health assessment.

Comment 12: We respectfully request that the ATSDR consider the reference document, Split Sampling Results, May 14, 1999, in making the determinations to be included in the final public health assessment. (Document provided by commentor.)

Response 12: ATSDR thanks the commentor for providing additional groundwater and soil data for the Norledge area. A short description of the groundwater sampling event was added to Section 4.1 and the contaminant data are contained in Table 2, Appendix B. Contaminants were detected within the ranges reported in the public comment version of this document. There are no changes to the conclusions of this final public health assessment.

A short description of the soil sampling event was added to Section 4.2 and the contaminant data were included in Table 4, Appendix B. Contaminants were detected below health-based comparison values. Therefore, there are no changes to the conclusions of the final public health assessment.

Comment 13: We respectfully request that the ATSDR consider an April 1999 Norledge area groundwater sample collected by Compass Environmental and analyzed by Pace Analytical in making the determinations to be included in the final public health assessment. (Document provided by commentor.)

Response 13: ATSDR thanks the commentor for providing additional groundwater data for the Norledge area. A short description of the groundwater sampling event was added to Section 4.1 and the contaminant data are contained in Table 2, Appendix B. Total xylenes were detected above the maximum value reported in the public comment version of this document. However, there are no changes to the conclusions of this final public health assessment because residents are not exposed to Norledge area groundwater. Where there is no exposure, there can be no adverse health effects, regardless of the level of environmental contamination.

Comment 14: EPA is currently sampling basement air in response to ATSDR's recommendation. The decision whether to conduct additional testing will rest on the benzene levels found during the June 1999, testing. Testing for all constituents of BTEX should be performed and factored into any decision making.

Response 14: EPA conducted sampling during June and July 1999 for volatile organic compounds (VOCs) which included BTEX (benzene, toluene, ethyl benzene, and xylene). ATSDR released a public health assessment addendum in March 2000 which provided an

evaluation of the June and July 1999 air sampling data as well as air sampling data collected in October 1999.

Comment 15: The EPA basement air sampling regime should be implemented across all seasons of the year. Dr. Brenner indicates in his report titled, BTEX Dose Model Report, June 24, 1996, that "[t]he U.S. EPA recommends an annual/seasonal sampling cycle. If this cannot be accomplished, then two sampling periods should be used which would represent the extremes of temporal concentrations." (BTEX Dose Model Report provided by commentor.) Dr. Brenner directs the reader to review U.S. EPA 540/1-89/002 Risk Assessment Guidance for Superfund Vol.I: Human Health Evaluation Manual (Part A) PB90-155581; 1989.

Response 15: The public comment version of this public health assessment evaluated air sampling data available to the agency at that time. The air data were collected in June, a warm month. Additional air data provided to the agency during the public comment period were collected in November, a cold month. Recent air data collected in June, July, and October 1999 were evaluated in a public health assessment addendum. Overall, ATSDR has evaluated data from both warm and cold months. The range of concentrations within the homes appears consistent.

Comment 16: Dr. Brenner emphasizes the need for annual/seasonal sampling cycles when he points out in his 1996 BTEX Dose Model Report that "[t]he soil gas study for the (Amoco) RFI failed to sample during different seasons, over a long enough period of time to ascertain the long term soil gas values."

Response 16: The soil gas sampling data provided in this document were collected in March 1995. Soil gas samples were not collected in a warm month. The specific levels of contaminants in soil gas might fluctuate during different seasons. However, for ATSDR's purposes, the March 1995 sampling data are considered sufficient because soil gas measurements are used by ATSDR only to help identify the contaminants that would be important to evaluate in air, and not used for exposure purposes.

Comment 17: Dr. Brenner in his 1996 BTEX Dose Model Report made the following statement: "Given the long operational history of the refinery and it's long record of releases of petroleum hydrocarbons, it is likely that the soil gas and indoor air BTEX concentrations were higher in previous years."

Response 17: No air or soil gas data are available from when the facility was operating; therefore, it is unknown what the levels of BTEX were in the past. One of the main purposes of this public health assessment, as stated in Section 2, is a review of data from the off-site Norledge area to determine if current exposures are of potential health concern for local residents. ATSDR's evaluation did not focus on evaluating potential past exposures because chemical-specific air data were not available for the agency to evaluate. However, ATSDR was informed in October 2000 that there may be some limited groundwater data from the 1960s and 1970s. The agency is currently evaluating the possibility of using this groundwater data to model past indoor air concentrations (see Section 6).

Comment 18: Dr. Brenner in his 1996 BTEX Dose Model Report made the following statement: "In addition, it appears that no sampling has been done to establish BTEX background values."

Response 18: At the time Dr. Brenner made this statement in 1996, no efforts had been made to establish background BTEX air levels in the Norledge area. However, typical background air levels for these compounds have been established for rural and industrial areas across the country. Benzene is specifically discussed in this public health assessment (see Appendix E). Also, since Dr. Brenner made his statement in 1996, various indoor and outdoor air sampling events have occurred characterizing the current BTEX air levels in the Norledge area.

Comment 19: Dr. Brenner in his 1996 BTEX Dose Model Report made the following statement: "It is

likely that anyone living in the area surrounding the former Amoco Sugar Creek Refinery received absorbed doses of the various BTEXs, via intrusion of BTEX soil gas, from just above background, to an order of magnitude or greater than background. Based on soil analyses, people also likely would have been exposed to other chemicals not modeled."

Response 19: No air or soil gas data are available from when the facility was operating; therefore, it is unknown what the types of chemicals and levels of contaminants were in the past (see Response 17).

Comment 20: Dr. Brenner in his 1996 BTEX Dose Model Report made the following statement: "If someone resided in the area during the period of time when the refinery operated, they would likely have also received additional doses due to air emissions from the refinery due to operational emissions and losses, as well as contaminated surface water."

Response 20: One of the main purposes of this public health assessment, as stated in Section 2, is a review of data from the off-site Norledge area to determine if current exposures are of potential health concern for local residents. ATSDR's evaluation did not focus on evaluating potential past exposures (see Response 17).

Comment 21: ATSDR's public health assessment evaluation focused on off-site air and soil gas. ATSDR should consider the soil gas sampling conducted for and contained in the 1995 Revised RFI report in those areas on-site, but up gradient from the neighborhoods. ATSDR should recommend that EPA require additional soil gas testing on-site, specifically in those areas where groundwater migrates from Amoco to the surrounding neighborhoods.

Response 21: For ATSDR's purposes, the off-site March 1995 soil gas sampling data are considered sufficient because soil gas measurements are used by ATSDR only to help identify the contaminants that would be important to evaluate in air, and not used for exposure purposes (see Response 16).

Comment 22: A groundwater sample collected by Amoco from monitoring well 62R in January, 1999, showed no detection for benzene. Weeks prior to that sample, Hydro-LOGIC collected and analyzed a perched groundwater sample approximately 45 feet from well 62R. This sample showed benzene in groundwater at concentrations of 1,720 ppb. Since ATSDR's public health assessment focuses on gaseous volatile organic compounds ("VOCs") migrating upward toward the ground surface, ATSDR should discount any groundwater monitoring data from Amoco's monitoring wells, and instead request that EPA order Amoco to perform a through study of soils and groundwater, including perched groundwater, in the residential neighborhoods. (Documents provided by commentor.)

Response 22: Concentrations of contaminants in groundwater will vary due to many factors. For instance, wells located only a few feet apart may have entirely different concentrations of contaminants due to well depth and/or geologic factors. ATSDR will not discount Amoco's sampling based on the documents provided by the commentor. Because quality control/quality assurance procedures were followed, ATSDR considers the data useful. Additionally, a system of wells in the Norledge area monitor groundwater conditions on a quarterly basis. Further, the EPA conducted a study of soils in Norledge area residential neighborhoods (surface soil sampling was conducted after the public comment release of this document in May 1999).

Comment 23: The final public health assessment should not consider Amoco's flawed basement air sampling conducted in Norledge area homes in 1991 and 1993. (Documents provided by commentor.) A cursory review of the documentation of Amoco's "do it yourself" air sampling shows that:

- Organic vapor monitors were installed in a Norledge area home on August 1 and 2, 1991, and received by the laboratory four days later.

Organic vapor monitors were installed in a different Norledge area home on December 2, 1993, and removed on December 3, 1993. The monitors were shipped four days later by Amoco's Health & Safety Officer to the laboratory and received by the laboratory on December 8, 1993.

- In both instances, Amoco qualified the safety of the sample analysis results to the property owners in terms of OSHA standards, without informing them that OSHA standards are based on exposures lasting 8 hours per day, 5 days per week.
- Amoco did not prepare or file with the EPA an air sampling work plan for either of these sampling events. This existing documentation doesn't indicate how the monitors were handled or prepared for shipping.
- Amoco misreports at Section 8-4 in the Revised RFI Report that Environmental Science Services conducted the sampling at the first home in 1991. Amoco performed the sampling itself. (Document provided by commentor).

Response 23: ATSDR did not consider the sampling data from homes sampled in August 1991 and December 1993 in the May 1999 release of this public health assessment. Benzene was not detected in the August 1991 sampling; however, this sampling event had a detection limit for benzene of 50 ppb. This value is either equal to or above ATSDR's health-based comparison values for benzene (i.e., CREG of 0.03 ppb, IEMEG of 4 ppb, and acute EMEG of 50 ppb). The December 1993 sampling event detected benzene at 6 ppb, which is within the range reported in this public health assessment. The other compounds (toluene, ethyl benzene, and xylenes) were not detected during either sampling event. For clarification of the specific concerns mentioned in this comment, ATSDR refers the commentor to EPA.

Comment 24: Dr. Otto Wong, an expert hired by Amoco, stated in a report dated September 11, 1996, that another Amoco expert, Dr. Laura Green, also estimated air benzene concentrations and calculated estimates of air benzene concentrations ranging from 3 ppb to 9 ppb. Dr. Green's findings for the benefit of Amoco are significant in that the EPA's "Quality Assurance Project Plan for Sampling and Analysis of Benzene at the Former Amoco Oil Refinery Sites" dated January 17, 1999, indicates at page 4 that "(T)he benzene action level for chronic exposure has been established by EPA Region VII in consultation with ATSDR as 7 ppb (22 ug/m^3)." Please comment on these chronic levels in the final public health assessment. (Documents provided by commentor.)

Response 24: The fact that EPA has set a site specific action level "in consultation with ATSDR" should not be interpreted to mean that ATSDR has officially designated that action level as being the equivalent of a public health hazard. Such an interpretation would not only be incorrect, it would be inconsistent with all of ATSDR's basic practices and policies. Neither the measured benzene levels in homes of the Norledge area nor any of the other exposure levels specified in this comment (3-9 ppb) would be expected to produce any cancerous or non-cancerous adverse health effects, even under conditions of chronic exposure. (For additional information on benzene, please see Appendix E.)

Comment 25: The initial public health assessment fails to evaluate the presence of heavy metals in the neighborhood soil and groundwater. Heavy metals characteristically found in refinery waste are known to be hazardous. In his deposition, Dr. Teitelbaum comments on the lack of study for toxic metals. (Document provided by commentor.)

Response 25: The public comment version of this public health assessment reviewed available environmental data collected in the Norledge area. Soil and groundwater samples were primarily analyzed for BTEX, not heavy metals. The presence of heavy metals in groundwater would not affect the conclusions of this public health assessment because no one has been identified as drinking the groundwater in the Norledge area; where there is no exposure, there can be no adverse health effects. Surface soil data (0 to 3 inches in depth)

were not available for ATSDR to review in the May 1999 release of this public health assessment. However, the EPA has since then conducted surface soil sampling (in February 2000) that included analysis for heavy metals. ATSDR's evaluated this surface soil data and concluded that no adverse health effects would be expected for adults or children from exposure to this soil during activities such as gardening or playing.

Comment 26: At other refinery sites where ATSDR has conducted risk assessments, particularly at those refinery sites being cleaned up under the Comprehensive Environmental Response, Compensation, and Liability Act ("CERCLA"), 42 U.S.C. §§ 9601, et seq., heavy metals and their probable pathways into neighborhoods are always considered. In some instances, the heavy metals create the primary risk to human health from the refinery:

- Double Eagle Refinery Co. Site, Oklahoma City, OK
- Prewitt Abandoned Refinery, Prewitt, NM
- Sinclair Refinery, Wellsville, NY
- Old Inger Refinery, Darrow, LA
- Old Citgo Refinery, Bossier City, LA
- Arrowhead Refinery Company, Hermanntown MN
- Fourth Street Abandoned Refinery, Oklahoma City, OK

Please explain how ATSDR can issue a final public health assessment for Sugar Creek with no consideration given to the heavy metals used and spilled at the refinery up gradient from the neighborhoods, creeks, and springs, including but not limited to lead, mercury, arsenic, barium, zinc, cadmium, cyanide, selenium, and chromium.

Response 26: ATSDR focuses its evaluations on completed pathways of exposure. Indoor air exposures were identified as the only current completed exposure pathway in the Norledge area. Heavy metals would not be expected to be currently affecting the indoor air pathway. Groundwater in the Norledge area is considered an eliminated exposure pathway. Surface soil data, which included analysis for heavy metals, have been evaluated in a health consultation and ATSDR concluded that no adverse health effects would be expected for adults or children from exposure to this soil during activities such as gardening or playing (see Response 25). Additionally, limited surface water and sediment data, which included analysis for heavy metals, have been evaluated in a health consultation and ATSDR concluded that the contaminants in these media are not a public health threat to residents in the Norledge neighborhood.

Comment 27: Please explain how any health assessment can be issued without one example data point for heavy metals in the neighborhood soil and groundwater. Please offer a rational for any such incomplete report, including the evidentiary and theoretical basis for it.

Response 27: ATSDR bases its findings on data that are available at the time the evaluation is conducted. If the data are insufficient, ATSDR recommends additional sampling. The presence of heavy metals in groundwater would not affect the conclusions of this public health assessment because no one has been identified as drinking the groundwater in the Norledge area. However, for the May 1999 release of this public health assessment, data for surface soil were found to be insufficient. As stated in the Conclusions Update (Section 8), ATSDR had previously concluded that the Amoco Oil Company site in Sugar Creek, Missouri, posed an *"Indeterminate Public Health Hazard*." ATSDR recommended sampling surface soil. The EPA has since then conducted surface soil sampling (in February 2000) that included analysis for heavy metals. ATSDR's evaluated this surface soil data and concluded that no adverse health effects would be expected for adults or children from exposure to this soil during activities such as gardening or playing (see Response 25 and 26).

Comment 28: No thorough historical review of Amoco's operation of the Refinery and its impact on the

neighborhood has ever been performed by any government agency, including ATSDR. The site's history should be evaluated, considered, and referenced in ATSDR's final report. If the final public health assessment indicates facts other than those presented in the accompanying documentation, please cite the source of the contrary information. (Documents provided by commentor.)

Response 28: The purpose of this public health assessment is to review available environmental data from the Norledge area to determine if current exposures are of potential health concern, not perform a thorough historical review of Amoco operations. Section 3 of this document contains the background information considered relevant for the purpose of this public health assessment. Section 10 discusses past and future ATSDR activities with regard to the Amoco site.

Comment 29: ATSDR should explain in its final public health assessment why this site, with its corporate, environmental, and regulatory history should be investigated, evaluated, and ranked differently than those refinery sites cited in Comment 26.

Response 29: ATSDR conducts site-specific health evaluations based on available data and information. ATSDR focused this public health assessment on the Norledge area of Sugar Creek because off-site groundwater contamination had migrated into the Norledge residential area. ATSDR's public health assessment process for evaluating environmental data at the Amoco site is not different than the process this agency followed at the refinery sites mentioned in Comment 26. Also, ATSDR is not an enforcement agency. We do not investigate, evaluate or rank sites - rather we evaluate public health implications.

Comment 30: As recently as March, 1994, the true status of groundwater use had not been definitively established and there is a history of confusion about the existence and use of groundwater wells. For example, an internal Amoco document indicates that as of March 11, 1994, 236 residents had not been surveyed on the use of personal water wells or groundwater use. (Document provided by commentor.)

Response 30: The March 11, 1994, document defined the private well survey as encompassing an area within approximately a one-mile radius of the facility (Amoco Oil Company, 1994a). The document stated that 236 of the residents in the Sugar Creek Survey were unable to be reached. Some of these residents were located in the Norledge area. The March 1994 document stated that efforts would be made to contact these remaining residents to determine if anyone had a private well. In an April 1994 follow-up survey, 21 residents were contacted about owning a private well, that is, only those residences located in the Norledge area (Amoco Oil Company, 1994b). All 21 responses were "no" to owning a well. Therefore, no confusion exists with regard to private drinking water wells in the Norledge area. No one is currently using private water wells in the Norledge area for drinking water.

The April 1994 document also stated that the remainder of the residents, located outside the Norledge area, would be contacted as part of the RFI Work Plan Addendum (Amoco Oil Company, 1994b). For more information on current RFI activities, ATSDR refers the commentor to EPA.

Comment 31: As recently as November, 1995, the true status of groundwater use had not been definitively established and there is a history of confusion about the existence and use of groundwater wells. (Documents provided by commentor.)

Response 31: A November 1995 letter stated that Amoco representatives visited a Sugar Creek resident about the status of a private well (TriTechnics Corporation, 1995a). The November letter indicated the well was not in an area impacted by refinery operations. At the time, the family was no longer using the well for drinking water (they had a bottled water system.) It is unclear to ATSDR staff how this letter adds to any confusion about the existence and use

of groundwater wells in the Norledge area.

Comment 32: Surveys found at least one residence was using the groundwater for "watering and drinking". (Document provided by commentor.)

Response 32: The commentor provided a piece of paper, not dated or a part of any specific reference document, that showed results of a survey indicating an address that had a well used for "water and drinking". ATSDR staff used a map program to find the location of the well with reference to the Amoco site and the Norledge area. The map program showed an address that is outside the Norledge area and to the east of the Amoco site. As stated previously, no one is currently using private water wells in the Norledge area for drinking water.

Comment 33: These wells referred to in Comments 30, 31, and 32 should be identified in the final public health assessment. Since these wells represent completed pathways, ATSDR should request that EPA, not Amoco, perform an investigation fully characterizing groundwater usage in the contaminated zone.

Response 33: As stated in Responses 30, 31, and 32, no drinking water wells were identified in the Norledge area. Therefore, no completed exposure pathway to groundwater currently exists for Norledge area residents. One private well was identified in the Norledge area that was used only for irrigation purposes in the past (Amoco Oil Company, 1994a). Amoco representatives requested the resident not use this well for any purposes. The City of Independence and the City of Sugar Creek water departments verified for Amoco representatives that all residences in the area of concern (i.e., the Norledge area) were hooked up to city supplied water (Amoco Oil Company, 1994a). This information was provided to EPA by Amoco.

Comment 34: In this public health assessment, ATSDR recommends: "(P)revent potential future exposures to contaminated groundwater, including placement of institutional controls on the installation of wells in areas of known groundwater contamination." ATSDR relied on Amoco's 1995 Revised RFI when stating in the initial public health assessment that no residents in the Norledge area own a well. That statement is simply untrue and should be corrected in the final public health assessment. It is difficult to understand how such a mistake could have occurred considering that ATSDR refers to two of these wells as being sampled in July, 1998.

Response 34: ATSDR did not mean to imply that no private wells exist in the Norledge area, only that no residents currently use private wells for household purposes. Sentences clarifying this issue have been added to the main text of the document.

Comment 35: The final public health assessment should follow the criteria established at other refinery sites and recommend that the groundwater under residences and source areas up gradient from residences be cleaned up to MCLs.

Response 35: As a non-regulatory agency, ATSDR's recommendations are meant to be general statements that serve as a guide for regulatory agencies and/or the potentially responsible party to follow. The contaminant clean-up levels are established by regulatory agencies. In response to this comment, ATSDR has added a general recommendation to section 9 stating: "Continue to remediate contaminated groundwater in the Norledge area".

Comment 36: In this public health assessment, ATSDR states "[t]he site and surrounding area have been provided with municipal drinking water since the 1920's; therefore, past and current exposures to groundwater constitute an eliminated exposure pathway." ATSDR presumes that once water is treated by a municipal waterworks, it is safe.

Response 36: The sentences in question do not presume that once water is treated by a municipal waterworks, it is safe. These sentences do not state either way, whether or not a water

supply is safe. These sentences only discuss whether exposure is possible, not what the potential health effects could be (health effects are discussed in the Toxicologic Evaluation, Section 5). What the sentences do state is that because residents were provided with drinking water from an entity other than the groundwater under their homes, they are not exposed to the groundwater under their homes. The groundwater under their homes is an eliminated exposure pathway. To clarify the sentence, it has been changed to, "[t]he site and surrounding area have been provided with municipal drinking water since the 1920's; therefore, past and current exposures to Norledge area groundwater constitute an eliminated exposure pathway." Additionally, the municipal water supply is regulated by the Safe Drinking Water Act and subject to state and federal drinking water standards.

Comment 37: In the 1920's, the Independence Water Supply sued Amoco (then Standard Oil of Indiana) for pollution of the water company's intake pipes. The water company had been ordered by the Public Service Commission to find another source of safe water. Water company experts and employees describe in sworn affidavits the quality of the water polluted by Amoco. (Document provided by commentor.)

Response 37: ATSDR's focus for this public health assessment is the Norledge area of Sugar Creek, not the Independence Water Supply. For more information regarding this concern, ATSDR refers the commentor to the Independence Water Supply.

Comment 38: The presumption of water being safe if from a municipal waterworks is put into perspective by Dr. Teitelbaum, where he states with a reasonable degree of medical certainty that water ingestion was a route of exposure for Sugar Creek residents. (Document provided by commentor.)

Response 38: Dr. Teitelbaum's statement is based on potential past intermittent exposures from drinking municipal water collected from the Missouri river. No environmental or medical data from the past are available to validate or refute his statement. With regard to the safety of municipal water, refer to Responses 36 and 37.

Comment 39: No thorough study has ever been required of Amoco to determine if the 8 - 35 million gallon hazardous waste spill under the lower refinery area is migrating down stream toward the Independence Water wells which today supply drinking water to over 200,000 users. No trenching has ever been conducted or required to bedrock east of the RCRA lagoons to determine whether preferential pathways carry the subterranean waste down stream toward the water wells. Jacobs Engineering, in a study performed under contract with EPA, determined that benzene and other pollutants were, in fact, dissolving into the Missouri River alluvium and, thence, to the Missouri River from the site.

Response 39: As stated previously, one of the main purposes of this public health assessment is a review of data from the off-site Norledge area to determine if current exposures are of potential health concern for local residents. This comment is outside the purview of the public health assessment. ATSDR directs the commentor to EPA for further information about the ramifications of the Jacobs Engineering study.

Comment 40: ATSDR should change its determination that water ingestion is an eliminated past exposure pathway. The public health assessment fails to include any discussion or review of documents from the waterworks supplying Sugar Creek and Independence. Until sufficient investigation and study have been performed by qualified specialists of the lower refinery contamination and its proximity to the water supply intake, ATSDR should change its determination that no current exposure pathway exists.

Response 40: ATSDR specifically made the statement that groundwater ingestion is an eliminated pathway with regard to Norledge area residents drinking the contaminated water beneath their homes (see Responses 36 and 37).

Comment 41: ATSDR should explain why at the other refinery sites described in Comment 26, the

regulators were concerned over any drinking water intake within a three mile radius of the facility, but no such urgency appears to be present at this site. None of the other refinery sites mentioned herein had 25% of the human water users than are present in Eastern Jackson County.

Response 41: As stated previously, this public health assessment focused specifically on the Norledge area. Further, ATSDR is a non-regulatory agency. To determine why regulators are concerned about a three mile radius at those sites mentioned in Comment 26, the commentor should contact the regulatory agency involved. Typically, ATSDR evaluations consider a one mile radius surrounding sites.

Comment 42: ATSDR should investigate all local governmental entities and public health agencies as sources for historical complaints and health investigations.

Response 42: ATSDR collected community health concerns from local residents in July 1998 and continues to on a regular basis. ATSDR is providing technical assistance to MDOH in it's current cancer health investigation. ATSDR is working with the City of Independence Health Department, the Jackson County Health Department, the Regional and National Multiple Sclerosis Society, the American Cancer Foundation, city and county elected officials, MDNR, and EPA. ATSDR has talked with EPA and ATSDR staff in Region VIII about activities at another Amoco refinery. ATSDR Region VII staff have met with Amoco medical and epidemiological staff to discuss workers' health issues and cohort studies and with the University of Alabama staff investigating the brain cancer cluster at the Napierville Research Center. As other entities are identified, ATSDR will include them in our evaluations.

Comment 43: It is well known in Sugar Creek and Independence that "fill" dirt could be obtained from Amoco's refinery upon request for use on residential property to fill gullies, depressions, or whatever other purposes the homeowner required. Depending on the nature, composition, and refinery source of the "fill" dirt, localized pockets of Refinery generated contamination which may be impacting human health currently exist outside and away from the Norledge plume area. Amoco should be required to disclose to the EPA and ATSDR all off-refinery areas where it has deposited soil, "fill" dirt or other debris generated by or from the Refinery.

Response 43: This public health assessment focuses specifically on the Norledge area of Sugar Creek; therefore, evaluating potential refinery generated contamination outside and away from the Norledge area is outside the scope of this document. With regard to the Norledge area, ATSDR has reviewed both surface and subsurface soil and determined no adverse health effects are likely to occur under current exposure conditions. However, if homeowners are concerned about fill material from Amoco, they should have the fill material in their yards sampled and analyzed. ATSDR would be available to evaluate the data for public health significance.

Comment 44: To further broaden the area potentially impacted by Amoco past and current operations, pipelines which transported crude oil and finished products, run through the neighborhoods south of Norledge Street. We have heard anecdotal stories of major leaks from these pipelines. ATSDR should ask that Amoco provide all documents in its possession concerning these leaks. Using that information of specific leaks, Amoco should be required to conduct soil, soil gas, and groundwater sampling along these pipelines. Only a finding of zero BTEX impact would be sufficient to rule out any areas potentially impacted by the pipe runs.

Response 44: Active petroleum pipelines currently exist on the eastern portion of the site and enter the site from off-site along the eastern and northern borders (Amoco, 2000). The pipelines are not near the Norledge area and are therefore outside the purview of this public health assessment.

Comment 45: ATSDR recommends that "precautionary measures" be taken to "prevent worker and resident exposures to free product that may be encountered during drilling, building, and excavating subsurface soil in the Norledge area." In its final public health assessment, ATSDR should clarify the answers to questions from residents of the contaminated neighborhood, i.e., "[w]ho should a property owner call when encountering contaminated media - the EPA, MDNR or Amoco?" "Who will respond?" "What will be the 'safe' level?" "Will the encounter be reported to the EPA or MDNR and what are the consequences of reporting it?" "What happens if a worker/resident is exposed?" "What agency should be contacted then?" Would the ATSDR recommend that each new building permit issued for the Sugar Creek or Independence area near the Refinery be required to have a notice that "precautionary measures" must be on hand before excavation? Finally, what "precautionary measures" would ATSDR consider appropriate?

Response 45: ATSDR is a non-regulatory agency; therefore, our recommendations are not legally enforceable. ATSDR recommendations are specifically designed to be general statements that serve as a guide for regulatory agencies to follow. In this instance, the specific regulatory agency would vary based on the type of subsurface work to be preformed. EPA, MDNR and the City have developed a protocol for responding to these types of occurrences, as well as to odor complaints. If a resident finds oily soils they should contact the local fire department. The fire department will notify the MDNR regional office and EPA, as needed. If a worker or resident is exposed, the exposed individual should see a physician (and the worker should report the exposure to OSHA). All off-site areas should be remediated before site activities end.

Comment 46: It has been reported that experts from ATSDR attended and spoke at a public meeting in Sugar Creek following issuance of the initial public health assessment. At that meeting it was unclear to the attendees whether the environmental specialist who wrote the initial public health assessment understands the difference between an undiluted soil sample and a composite sample. Please address this issue in the final public health assessment if ATSDR relies on, or cites to, the Amoco Burton Street sewer excavation soil sample.

Response 46: ATSDR staff are aware of the various methods in which soil samples are collected, including the staff working on this public health assessment. The sewer soil sample data were included in this document specifically because the community questioned whether the soil would be sent to a landfill. ATSDR provided information relating to this soil sampling event in Section 4.2.

Comment 47: ATSDR uses the term "comparison value" in evaluating potential health risks and defines it in Appendix C as "media-specific...screening values." In addition, ATSDR irregularly refers to State of Missouri criteria (e.g. with regard to cleanup of hydrocarbon contaminated soil). ATSDR should make reference to Missouri criteria in all cases and particularly with respect to groundwater. For example, this is not done with regard to Missouri criteria for TPH due to either GRO or DRO in Tables 2, 3 and 4.

Response 47: ATSDR only referred to Missouri criteria in one instance, in Section 4.2, when describing soil samples taken during a sewer excavation. As stated in Response 46, Missouri criteria were mentioned in this instance only because the community questioned if soil from the sewer excavation would be sent to a landfill. The decision of whether to send the soil to a landfill depended upon the soil contaminant values in comparison to regulatory values determined by the state of Missouri.

Comment 48: It has also been reported that Dr. Frank Schnell expressed his opinion at the public meeting that benzene is not hazardous to humans in soil until the benzene concentrations reach 700,000 parts per million in soil. This concentration was confirmed with Dr. Schnell and Dr. Hewitt after the meeting, and again with Dr. Schnell by telephone to his office in Atlanta the day following the meeting. Dr. Schnell, speaking as an expert and as a

representative of ATSDR, stated that the 700,000 ppm level is not an official concentration level of the agency. In the telephone conversation, he clarified that his figures referenced an ingestion number for benzene, but this was not made clear at the public meeting. Since many members of the public will have no further exposure to the health issues than attendance at the public meeting, or perusing subsequent news media reports on the meeting, ATSDR should very clearly, and in plain English, present to the public its official position on the 700,000 ppm concentration level.

Response 48: Some confusion has arisen concerning a 700,000 ppm concentration of benzene in soil which Dr. Frank Schnell, an ATSDR toxicologist, mentioned at the Sugar Creek Public Meeting on June 2, 1999. This concentration does not represent an official "safe" level of benzene in soil. ATSDR does not have a non-cancer comparison value for benzene in soil. Solely for the purpose of putting into perspective a deep subsurface soil concentration of 177 ppm benzene found in subsurface soil in Sugar Creek, Dr. Schnell tried to describe what an ATSDR non-cancer comparison value for benzene in soil might be, if one existed. He derived his hypothetical comparison value from the following considerations.

No adverse effects are known to occur in either animals or humans exposed chronically to 1 mg/kg/day or less of benzene orally. Based on ATSDR's default assumptions regarding soil exposure, soil would have to contain 700,000 ppm benzene in order for a 70-kg adult to receive this No-Observed-Adverse Effect Level (NOAEL) dose of 1 mg benzene/kg body weight/day. But since 700,000 ppm would be equivalent to a NOAEL dose, and ATSDR's comparison values may be as much as 100-1,000 times lower than the NOAELs on which they are based, a non-cancer, comparison value for benzene in soil, if ATSDR had one, might be as low as 700 - 7,000 ppm.

This hypothetical comparison value for benzene in soil is based on non-cancer effects, only. ATSDR does have a cancer risk evaluation guide (CREG) of 20 ppm for benzene in soil. However, the CREG is based on chronic (i.e., lifelong) exposure. It is unlikely that chronic exposure occurred as the soil sample was taken at a depth of 12 - 14 feet below the ground surface.

Comment 49: Please comment on the veracity of Dr. Schnell's calculations, and include instructions on how to create a sample with a 700,000 ppm benzene concentration.

Response 49: See 2nd paragraph of Response 48. With regard as to "how to create a sample with 700,000 ppm benzene," a soil sample containing 700,000 ppm (or 70% by weight) benzene would be "wet" with pure benzene and, because benzene is a volatile organic solvent that evaporates rapidly in air, the concentration of 700,000 ppm benzene could not exist for very long in surface soil (unlike earth 12-14 feet below ground). That is why benzene in air, and not benzene in soil, is of primary concern to ATSDR. Air is the benzene-contaminated medium to which humans are most likely to be exposed at Sugar Creek or anywhere else, especially in amounts that may be of public health significance.

Comment 50: ATSDR has included no findings regarding chronic exposure to contaminants found in the Norledge area. The final public health assessment should include such a discussion. No determination of health threats can be made in the off-site area, without a finding regarding chronic exposure.

Response 50: ATSDR determined residents are exposed to contaminants in indoor air in their homes. Because limited indoor air data were available for ATSDR to review, ATSDR recommended additional indoor air sampling. ATSDR released a public health assessment addendum on March 29, 2000, that evaluated chronic exposures to indoor air in the Norledge area. As stated in the March 2000 public health assessment addendum, current, chronic exposures to the contaminant levels detected in indoor air in Norledge area homes are not likely to be associated with adverse health effects.

In this public health assessment, ATSDR did make several determinations with regard to public health implications. ATSDR determined that short-term exposures to the contaminant levels detected during the limited air sampling event are not likely to be associated with adverse health effects, that contaminated groundwater in the Norledge area is not a source of drinking water, that no residents are experiencing direct exposures to soil gas, and that potential intermittent exposures to subsurface soils in the Norledge area during drilling, building, and excavating would be unlikely to result in adverse health effects.

Comment 51: The final public health assessment should include the curriculum vitae of each person who works on either the report or any investigation leading up to issuance of the final report.

Response 51: It is not ATSDR policy to include curriculum vitae's of each person who works on a report in the final report. This public health assessment involved the work of a multi-disciplinary site team (an environmental scientist, a toxicologist, a medical doctor, a community involvement specialist, a health educator, an epidemiologist, and a regional representative). This public health assessment received peer reviews from agency staff before release to the public.

Comment 52: We object to the phrase "Indeterminate Public Health Hazard", because it suggests that there is known to be a hazard of some nature. On its face, this phrase is misleading and potentially could arouse unwarranted anxiety. A new phrase, such as "Inconclusive Public Health Hazard" would be more appropriate. If this phrase is a term of art which the agency is not free to alter, we suggest that the agency add clarifying test to the fact sheet, summary, and report to make this fact clear.

Response 52: The phrase "Indeterminate Public Health Hazard" is a formal conclusion category (see definition in Appendix G -- Glossary of Terms). To assist the reader, the same definition that is provided in the glossary is footnoted on each page it appears in the public health assessment's main text. The fact sheet is considered final; therefore, no changes have been made.

Comment 53: In the report, and in the fact sheet, a number of "concerns" are listed. These "concerns" include multiple sclerosis (MS) and Alzheimer's disease. Because of the format, the casual reader could conclude that increases of these health issues have been demonstrated at Sugar Creek. There is no quantitative evidence of increases in the incidence of these diseases in the Sugar Creek community.

Response 53: In Section 6, Community Health Concerns, ATSDR clearly states that because data regarding these diseases are not routinely collected by public health agencies, ATSDR was not able to state whether the incidence of these diseases is higher than expected in Sugar Creek. ATSDR further clarifies that these diseases have not been linked with any of the identified chemicals of concern in the Norledge area. ATSDR disagrees that the casual reader could conclude from these statements the agency found increases in these diseases.

Comment 54: The etiology of MS and Alzheimer's disease is not clearly defined, and at least with MS, the etiology is probably complex. Even in those cases in other places around the United States where clusters of MS have been identified, the significance and cause of these clusters is unknown. No MS cluster has been identified in the Sugar Creek area.

Response 54: The etiology of MS and Alzheimer's disease are discussed in this public health assessment (see Appendix F, Health Endpoints). ATSDR does not concur with the commentor's statement that "no MS cluster has been identified in the Sugar Creek area". No formal study of MS incidence has been conducted in the Sugar Creek area; therefore, it is not possible to say that no cluster exists. Similarly, without a formal study, it is not possible to say there is an increase in MS either. Currently, ATSDR's Division of Health Studies (DHS) is funding a multiple sclerosis (MS) prevalence study through the Jackson County

Health Department to determine if higher rates of MS exist in Sugar Creek and Independence.

Comment 55: Although there is some language qualifying the list of concerns or illnesses, the incorrect inference could be made that some environmental trigger, possibly perceived to be associated with the refinery site, could be causing increases of these illnesses in the investigated area of Sugar Creek.

Response 55: In Section 6 of the public health assessment, ATSDR clearly states that none of the contaminants, at the levels detected in the Norledge area, have been associated with MS, Alzheimer's, or nervous disorders. The community concern regarding cancer endpoints is being followed up by MDOH.

Comment 56: Including a list of concerns in the report could arouse unwarranted concern in this community and elsewhere and is inappropriate.

Response 56: Learning what people in the area know about a site and what concerns they may have about its impact on their health is of particular importance to ATSDR (see the Forward of this document). Responding to community health concerns is a major focus of the public health assessment process.

Comment 57: The list of 'concerns' should be removed from the fact sheet and executive summary, where there is no discussion putting these 'concerns' in their appropriate context (as there is in the report itself).

Response 57: The fact sheet is considered final; therefore, no changes have been made. In Section 1 (Summary), ATSDR states what the petitioner "believes" are the health issues related to the site. ATSDR feels the sentence in question is appropriate and not out of context.

Comment 58: The report uses terminology such as "incidence" and "cluster" which have both popular usage but also specific epidemiological meaning. At this point there is no statistically significant evidence of clustering or of increased incidence (risk) for any health endpoints at Sugar Creek. The epidemiological literature indicates that a substantial number of apparent clusters of illness may be expected due to chance alone. The likelihood of encountering chance clusters increases as more studies are done, more health endpoints examined, and more geographical area included in the studies. The use of epidemiological language should avoid giving the impression that definitive studies exist when they do not.

Response 58: ATSDR has correctly applied the term "incidence" in this report. Incidence refers to the relative frequency (rate) of the occurrence of a disease or diseases in a population. The rate is usually measured over a period of years and compared to a standard population where the expected rate or occurrence of that disease is known. ATSDR clearly states in Section 6 that data regarding most of the health endpoints (i.e., MS, Alzheimer's disease, and nervous disorders) of concern to the community are not routinely collected by public health agencies; therefore, the agency cannot determine if the incidence of these diseases is higher than expected. These statements in Section 6 do not imply definitive studies exist. The term "cluster" is not used in the main text of the document. MDOH is currently conducting studies (i.e., cancer investigations) in the Sugar Creek area.

Comment 59: We understand this inquiry was prompted by a citizen request which focused on Amoco. So that the public can fairly evaluate the current efforts to study the health of the Sugar Creek community, we believe that the text of the original request should be made available (without identifying the author).

Response 59: ATSDR does not typically include the text of petition letters in public health assessments. The concerns of the petitioner and community are summarized in Section 2 (Purpose and Health Issues). Requests for a copy of the original petition letter can be made to: Freedom of Information Act (FOIA) Office, Centers for Disease Control and Prevention, 1600

Clifton Road NE, Atlanta, Georgia, 30333, ATTN: Lynn Armstrong.

Comment 60: We believe that any inquiry regarding public health in the Sugar Creek community should be broader than the former Amoco refinery site. Although the specific request may be limited in its focus and wording by the petitioner, we believe that ATSDR has a responsibility to respond to any petition in the context of complete public health conditions.

Response 60: ATSDR agrees that any studies of the 'Sugar Creek community' in its entirety should be broader than the Amoco site; however, this initial public health assessment focuses on only a small portion of the Sugar Creek community, specifically the Norledge area. ATSDR documents can be very broad in focus like evaluating multiple exposure pathways for an entire site, or very narrow in focus like evaluating one exposure pathway in a defined area. For this public health assessment, the petitioner and local community expressed their concern about the health risks of known groundwater contamination migrating from the Amoco site into the Norledge area. In response, ATSDR evaluated available environmental data from the Norledge area.

Comment 61: While we believe that there is no evidence showing any increased illness or disease, we think it is misleading and unfair to suggest that the only potential source of contamination or exposure is Amoco. In order to properly respond to the citizen's concern, ATSDR should take a broader view. A number of sources and factors could lead to environmental conditions in the area. The study as focused inappropriately assumes that all environmental and health issues are linked to one source.

Response 61: As stated in Response 58, most of the health endpoints of concern to the community have not been studied (e.x., MS, Alzheimer's disease, and nervous disorders) so it is not possible to state whether there are or are not increases in these health endpoints. Based on site-specific exposures, none of the contaminants, at the levels detected in the Norledge area, have been associated with MS, Alzheimer's, or nervous disorders. ATSDR did not inappropriately assume all the health endpoints were linked to the Amoco site. In Appendix F, ATSDR provides the known sources and factors associated with these and other health endpoints. With regard to environmental issues, ATSDR's public health assessment did specifically evaluate environmental data for the Norledge area regardless of the source (see Response 60).

Comment 62: To avoid misguided anxiety and concern in the community, public presentation of results at public meetings or in the news media should be limited to the actual findings regarding available data and their interpretation.

Response 62: ATSDR staff strive to always present the results of site-specific evaluations to the public in a clear and concise manner.

Comment 63: The report notes that the levels of benzene detected in indoor air samples do not pose a short term risk to residents. However the report is silent on chronic risk, potentially causing the reader to become concerned about the long term health effects. We believe that the report should indicate that the levels found in the test homes are consistent with the range of normal variability found in typical households. The report should also note that there is no scientific evidence that the very low levels detected pose any risk, short-term or chronic.

Response 63: The air data available to the agency at the time the May 1999 public health assessment was released for public comment were limited and may not have been representative of chronic exposure levels (see Section 5.1.1). ATSDR did comment on typical indoor air levels of benzene (see Appendix E). In the May 1999 public health assessment, ATSDR recommended additional indoor air sampling. This air sampling was conducted in July and July of 1999. ATSDR released a public health assessment addendum on March 29, 2000, that evaluated chronic exposures to indoor air in the Norledge area. As stated in the March

2000 public health assessment addendum, current, chronic exposures to the contaminant levels detected in indoor air in Norledge area homes are not likely to be associated with adverse health effects.

Comment 64: The report makes repeated references to dichlorobenzene. In order to avoid confusion, we believe it is important to point out dichlorobenzene is not associated with petroleum products.

Response 64: In the public health assessment text, ATSDR stated the common sources of 1,4-dichlorobenzene (see Section 5.1.2).

Comment 65: The report notes that the highest readings of benzene were noted in the "background" homes, i.e., properties not on Amoco's contamination plume. The report correctly points out that these readings are the result of various household conditions. (Cigarette smoke, household chemicals and solvents, lack of adequate ventilation, etc.) However, the report is silent on the presence of these same conditions in the test homes, where readings were lower than the "background" homes.

Response 65: ATSDR refers to the two homes outside of Amoco's groundwater contamination plume as "control" homes, not "background" homes. ATSDR did not consider the readings taking in these two homes to represent background levels for the Sugar Creek area as the data were limited. The sentence in Section 5.1.1 the commentor is referring to has been changed to a more general statement which includes all homes tested: "Endogenous sources (e.g., second-hand tobacco smoke, auto exhaust from attached garages, glues, paints, and other domestic materials containing benzene) may have contributed to the benzene levels detected in these homes."

Comment 66: The report notes that access to the refinery is not restricted, implying that members of the community are being exposed on the property. First, we would note that inadvertent on-site exposures of limited duration pose no health risk. Second, site access is generally restricted by fencing and by site personnel. Virtually all access to the site is controlled.

Response 66: In a background section of the report, ATSDR has included a Physical Hazards section (see Section 3.3). This section discusses only potential physical, not chemical, hazards associated with the Amoco site. ATSDR did not review on-site environmental data, and therefore cannot comment on the health risk of on-site chemical exposures. ATSDR did state that several areas of the site are not restricted. Amoco has recently reviewed the issue of site access, with specific focus on the risk of unlawful entry, and is currently making further improvements to site access control.

Comment 67: Air samples were collected in October 1999. Please consider these results in the final Public Health Assessment for Sugar Creek. (Document provided by commentor.)

Response 67: ATSDR thanks the commentor for providing additional indoor air sampling data for the Norledge area. A short description of the sampling event was added to Section 4.4 and the additional data are contained in Table 7, Appendix B. Overall, the contaminants detected in air were in the same ranges as the air data previously provided in the public comment version of this document. Therefore, there are no changes to the conclusions of the final public health assessment.

Comment 68: Can I use my well (20,000 gallons approximate) for garden watering and a koi pond?

Response 68: The location of this well was not provided to ATSDR; however, the agency recommends that the commentor not use the well if it is located within the established Norledge groundwater contamination area.

Comment 69: Are we safe to live here?

Response 69: At the maximum concentrations detected to date from chemical-specific data, none of the contaminants identified in the Norledge area would be expected to produce adverse health

effects, under site-specific conditions of exposure.

Comment 70: What about the 5 brain tumors viewed on 1 porch since 1986, and 2 more if reviewed to 1984?

Response 70: Information on health endpoints should be provided to MDOH for consideration in their health investigation. Based on available environmental and toxicologic data, none of the contaminants detected in the Norledge area are at levels that would be associated with brain tumors, under current site-specific conditions of exposure.

Comment 71: What about the effects of chronic exposure before closure?

Response 71: Chemical-specific sampling data from when the facility was operating are not available; therefore, ATSDR cannot comment on past exposures. ATSDR did evaluate current environmental data to determine the public health implications of current and future potential exposures. ATSDR determined that no adverse health effects are likely under site-specific conditions of exposure (see Response 50).

Comment 72: The conclusion you reported supports Amoco's test results not independent tests showing conflicting results.

Response 72: ATSDR relied on a variety of reports, as well as independent test results submitted to the agency during the public comment period (see Response 1).

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